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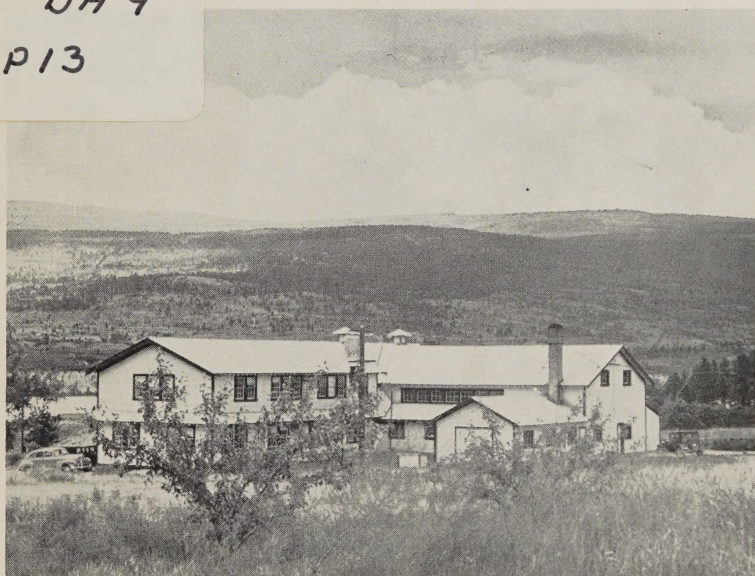
PRODUCTION of JUICES

*Their Manufacture,
Chemical Aspects and Laboratory Control*

By

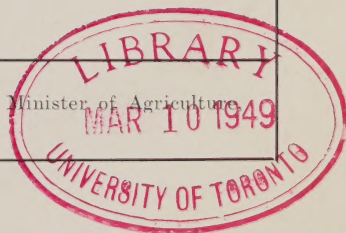
F. E. ATKINSON and C. C. STRACHAN


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Fruit and Vegetable Products Laboratory
DOMINION EXPERIMENTAL STATION
Summerland, B.C.

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Production of Juices

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Fruit and Vegetable Products Laboratory
Dominion Experimental Station
Summerland, B.C.

Commercial production of juices in Canada has been mainly limited to tomato, apple and grape. On a smaller scale, work has been done with some vegetables, such as celery, beet and carrot, and some of the berries such as raspberry and loganberry. Experiments have been conducted with the manufacture of juices such as cherry, and a combination of berry juices with apple. Nectars have also been made from apricot, peach and prune. In the manufacture of juices it has been the intention to preserve as much as possible of the flavour, colour and nutritive value of the original product from which the juice is made. These juices are intended as food to balance the diet, and not as a replacement or substitute for alcoholic beverages.

Tomato Juice

The commercial production of tomato juice in Canada for the years 1940 to 1946 inclusive is as follows:

TABLE 1—CANNED TOMATO JUICE

Year	Cases	Value
		\$
1940.....	1,506,972	2,207,338
1941.....	2,538,684	4,033,675
1942.....	2,041,508	3,871,558
1943.....	1,896,012	3,570,872
1944.....	3,415,220	6,602,958
1945.....	2,413,407	
1946.....	4,262,175	

The 5-year average covering the years 1940 to 1944 is 2,274,279 cases of 24-20 ounce cans, valued at \$4,057,380. The average for the years 1945 to 1946 is 3,337,791 cases of 24-20 ounce cans. This production of juice is from standard varieties grown for canning or the fresh market.

In the production of tomato juice the effort is to develop a juice with a colour as bright red as possible, with the natural flavour of tomatoes, and with as high an ascorbic acid content as the fresh fruit will permit. It should have a proper consistency that is neither too thick nor watery. The fruit should be well washed so as to remove any soil particles and trimmed to remove rots, or decaying portions. Immediately after trimming, it is milled, preheated, extracted, reheated, filled into cans, capped, cooked and quickly cooled. Some manu-

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² Food Technologist.

facturers are leaving out the final cook. In United States areas where *Bacillus thermoacidurans* is prevalent, a "high temperature short time" process is finding favour with processors.

GRADES

The following extract from the Meat and Canned Foods Act covers grading requirements for tomato juice.

(a) "Tomato Juice" shall be packed from the unconcentrated pasteurized liquid of the tomato with a proportion of the pulp expressed, with or without the application of heat and by any method which does not add water thereto, from whole, ripe tomatoes from which all stems and objectionable portions have been removed.

(b) If salt or sugar be used, it must be used dry or dissolved in the juice that comes from the tomatoes. Brine made from water and sugar or salt or both is prohibited.

(c) "Fancy Quality Tomato Juice"—Has the flavour of well ripened tomatoes, good consistency and free from particles of skin, seeds and minute pieces of core; the colour of this grade shall be equal to or better than the colour designated "Dull Terra Cotta" (No. 4) plate 331, Repertoire de Couleurs, except that it must be somewhat more pink, or that produced by spinning a combination of the following Munsell colour disks; 70 per cent (5R 2.6/13—glossy finish); 15 per cent (2.5YR 5/12—glossy finish); 5 per cent (N1—glossy finish); 10 per cent (N4—matte finish).

(d) "Choice Quality Tomato Juice"—Has the flavour of well ripened tomatoes, fairly good consistency and practically free from particles of skin, seeds and minute pieces of core; the colour for this grade shall be equal to or better than the same tone as, but slightly less orange than, the colour designated "Dull Terra Cotta" (No. 4) plate 331, Repertoire de Couleurs, or that produced by spinning a combination of the following Munsell colour disks; 67 per cent (5R 2.6/13—glossy finish); 20 per cent (2.5YR 5/12—glossy finish); 4 per cent (N1—glossy finish); 9 per cent (N4—matte finish).

(e) All containers of tomato juice shall be coded daily.

In tomato juice, mould filaments shall not appear in more than 25 per cent of the microscopic field; bacteria shall not exceed fifty million per cubic centimetre; yeasts and spores shall not exceed 65 per $\frac{1}{60}$ cubic millimetre.

The copper content of tomato products shall not exceed 50 parts per million of dried total solids.

PROCESS

To obtain the desirable qualities in a tomato juice, a line as depicted in Figure 1 may be employed. The various items in this line are indicated by numbers from 1 to 24. 1 on the drawing indicates a half round steel flume of a minimum of 50 feet in length and 14 inches in diameter. Some have been built 90 feet long and 20 inches diameter. This flume need not be in a straight line and can be used to convey tomatoes from the receiving platform to the remainder of the line. The important object of this part of the system is to loosen the adhering dirt especially the clay that is characteristic of some tomato growing areas. The flume is particularly adapted to this purpose as the tomatoes receive considerable agitation as they pass down it to the soaker tank 4. Only sufficient grade is put on the flume so that it will drain dry after cleaning, for example 2 inches in 50 feet. (This flume is sometimes replaced by an additional soaker tank.)

As the tomatoes emerge from the flume they pass over a slatted grill above tank 3, where the water from the flume is recirculated by pump 2. A baffle

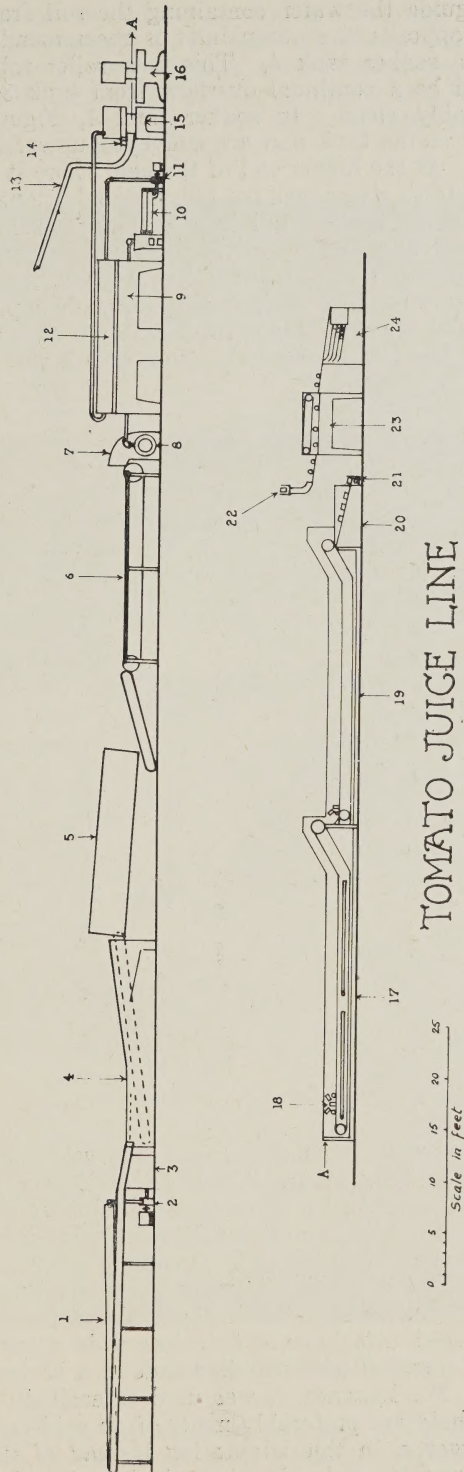


FIG. 1. A Continuous Tomato Juice Line

placed in tank 3 to guide the water containing the soil from the tomatoes to the side of the tank opposite the pump inlet is recommended. The tomatoes continue and fall into soaker tank 4. This is a roller table, soak tank and washer. There should be a continual overflow from tank 3 so that the water is maintained reasonably clean. In soaker tank 4, Figure 2, the tomatoes fall into the deep end of the tank and are conveyed upwards and forwards by means of a roller belt. At the higher end of the belt where it is out of the water but covered, sprays of fresh water give the tomatoes additional cleansing. From the soaker tank belt the tomatoes fall into a rotary washer 5, see Figure 3, where they are agitated and exposed to sprays of water under high pressure (approximately 125 pounds). The quantity of water and the pressure should be sufficient so that the tomatoes that are soft will become completely disintegrated and be washed down the drain at this point. This machine may be eliminated if no trouble is encountered in keeping the pack within the government mould count tolerance.

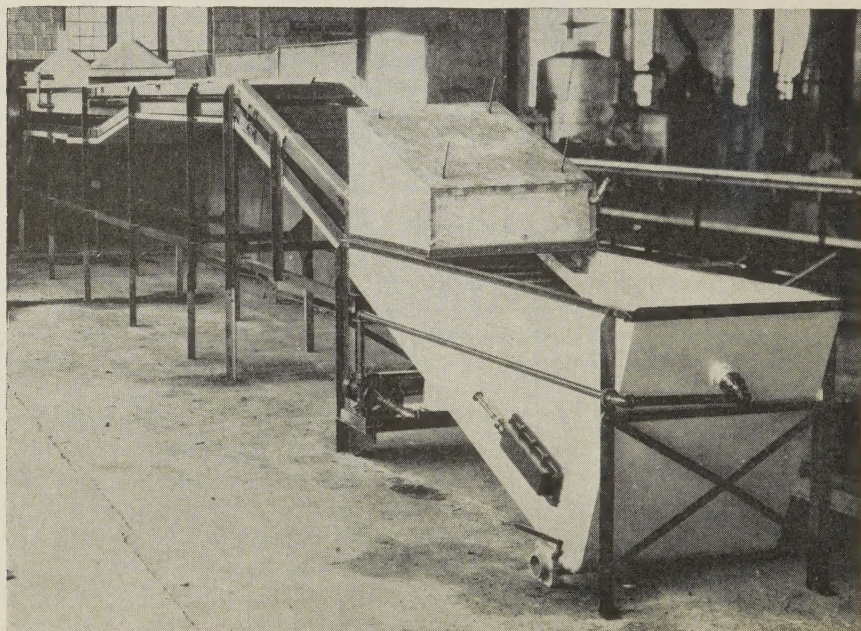


FIG. 2. Roller Table Soak Tank

Firm, wholesome tomatoes continue through this washer and up an elevator onto inspection roller belt 6, Figure 4. Here cracks or other defects are removed. The tomatoes are rolled over as they pass before the trimmers. The length of roller belt shown in this drawing is relatively short—about 20 feet. With this length of belt one of two things is necessary, either a very high quality of tomato, or some method of rapid trimming. One company has solved this problem by placing an endless pintle link chain above the rubber belt. This chain has diamond-shaped attachments 5 inches wide attached to the links. Normally this chain is operated with the diamonds in a horizontal position and is used for conveying. For instance, it was used extensively in exhaust boxes. The diamonds on the chain are preferably made of an acid-resistant metal such as stainless steel. However, in this adaptation instead of the diamond being flat or in a horizontal position it is placed vertical, and each upward diamond

point is used to impale tomatoes that require trimming. The women operators place the part of the tomato to be trimmed always on the same side of the diamond link. As the chain progresses it eventually passes under a sharp knife on the same side of the belt as the portion of tomato that is to be trimmed. When the operators merely have to impale the tomatoes and not actually perform the trimming, the operation is accelerated.

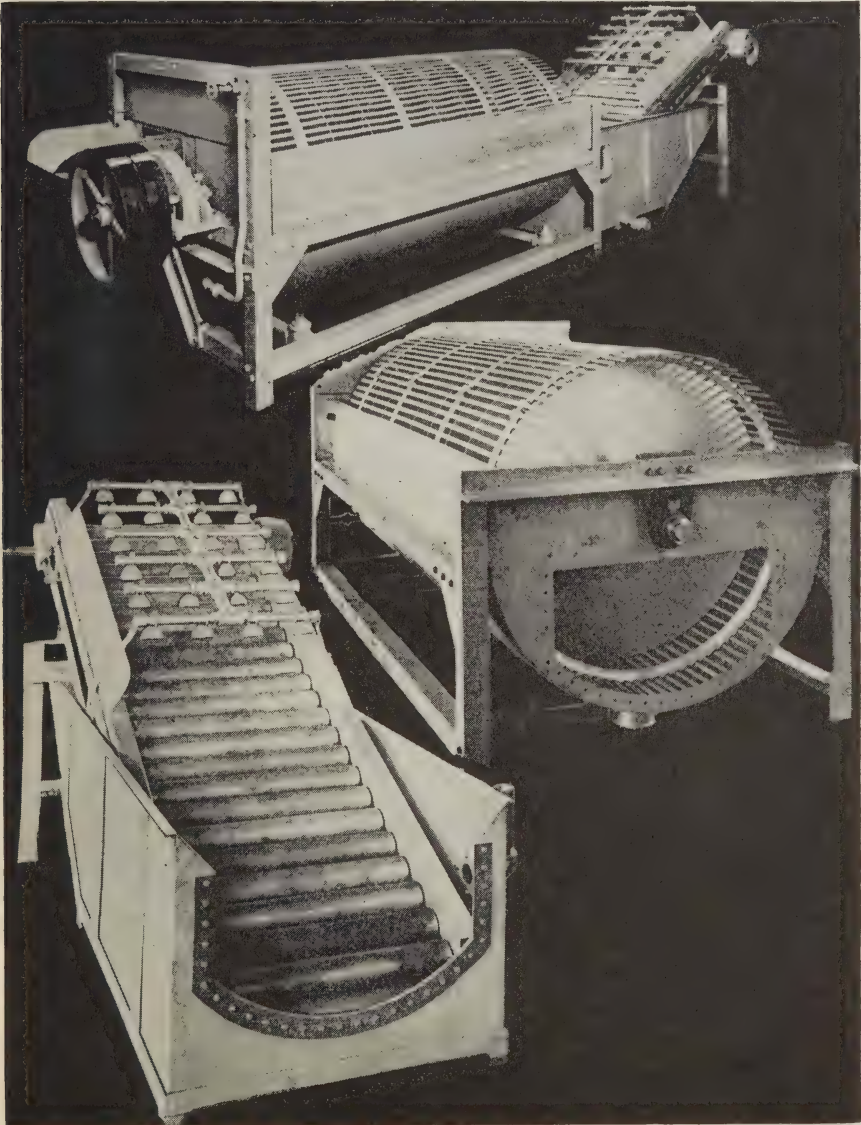


FIG. 3. Rotary Tomato Washer

From the trim belt, the tomatoes fall into a tomato mill 7, Figure 5, and are ground sufficiently fine so that they may be passed through a nickel alloy pump 8, and through a preheater 9, Figure 6. Considerable significance is

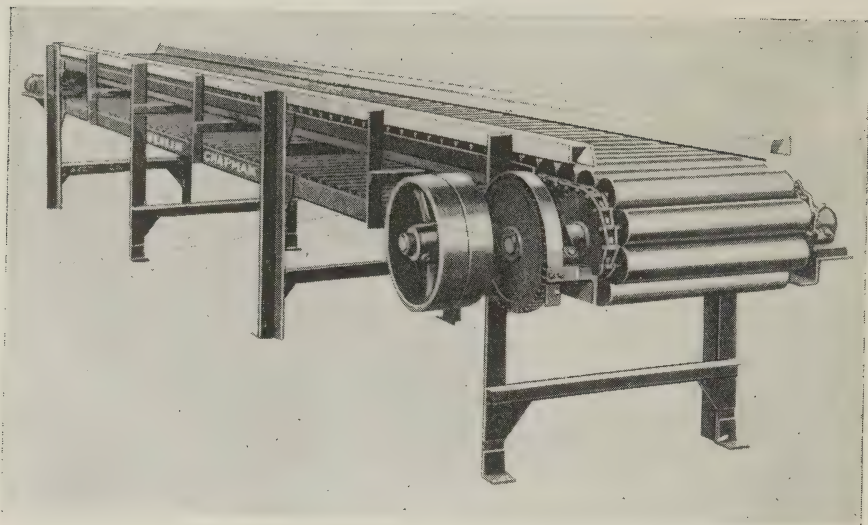


FIG. 4. Roller Inspection Belt

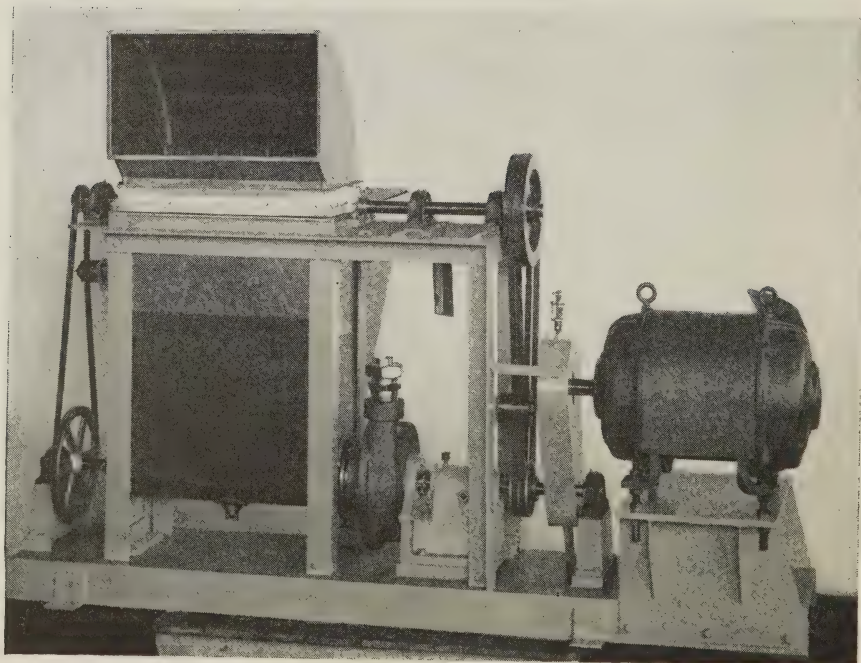


FIG. 5. A Tomato Mill

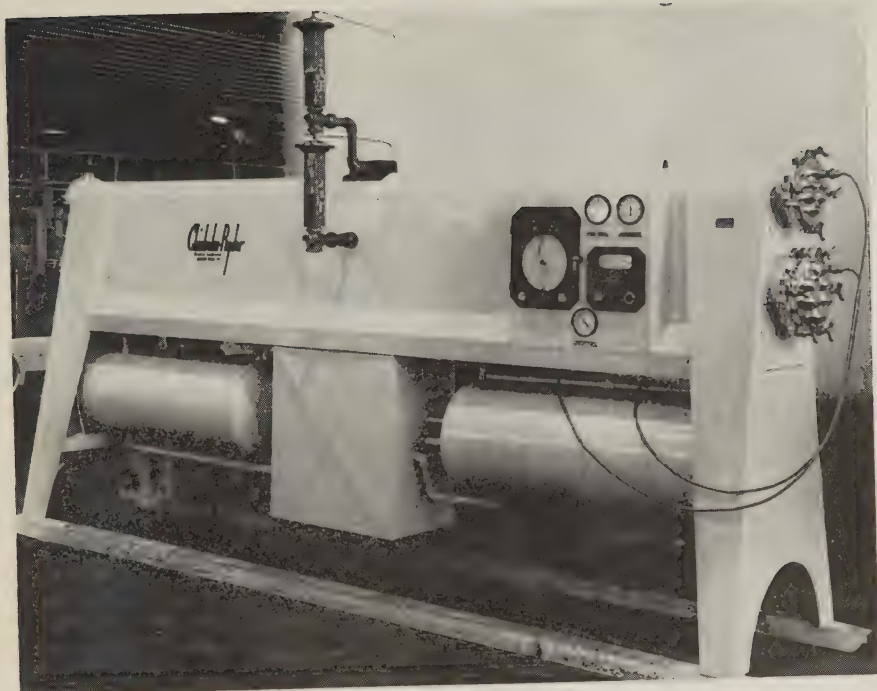


FIG. 6. Combination Preheater and Pasteurizer.

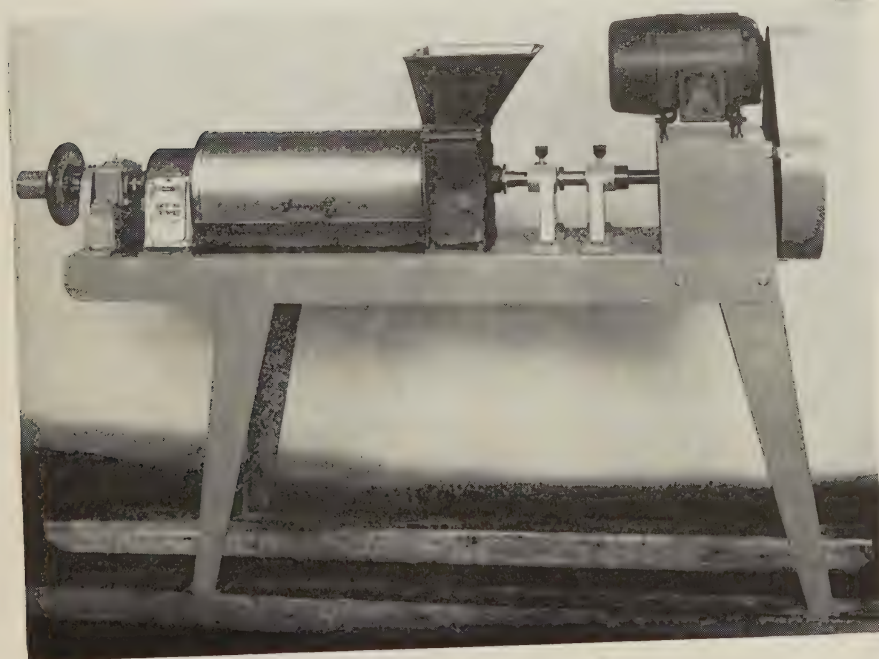


FIG. 7. Tomato Juice Extractor

attached to this part of the process. After the tomatoes have been milled the sooner they can be heated to a temperature of at least 190° F., the more ascorbic acid will be retained if the remainder of the process is properly handled. In the accompanying drawing, the time from the milling of the tomato until it is preheated to 190° F. or higher is only a few seconds.

The heated milled tomatoes then pass from the preheater into the tomato juice extractor 10, Figure 7. This machine is of stainless steel or other nickel alloy and is of the expeller-extractor type. The screen perforations usually are 0.020 of an inch and there is an adjustable clearance at the end of the screen so that the desired pressure can be easily obtained. The usual setting at this point is for a yield of 65 to 70 per cent of the tomatoes as juice. A second nickel alloy pump 11 takes the juice from the extractor and passes it through the pasteurizer 12 to heat it again to 190-195° F. for filling.

The filling operation takes place at 15, Figure 8, this machine being supplied with clean cans from the can track 13. A can washer on the empty can supply line is not shown in the drawing but is illustrated in Figure 9. Before these cans are filled, a salt tablet is deposited by an automatic salt dispenser 14. Some plants have adopted the policy of using two salt tablet dispensers, each putting in a tablet of half the usual size. By this method, if one machine is out of operation the can will always get half a tablet.

From the filling machine the cans pass through the closing machine (16). Between these two machines there is another important point. The filling machine 15 will probably be set to handle 125 to 225 cans per minute. The can transfer between filler and capper must be sufficiently smooth so that undue spillage is avoided. Figure 8 illustrates a satisfactory set-up. Experiments have shown that the loss in ascorbic acid content in tomato juice in the can is proportional to the headspace (3). In other words the loss in ascorbic acid is proportional to the oxygen contained in the headspace. (15, 43). Consequently it is desirable to close the cans while they are still as full as possible.

From the closing machine, the cans roll into a track that conveys them into a cooker 17. Here the cans receive a cook of 8-12 minutes at 208° F. and then are cooled in a draper belt cooler 19. Draper belt cookers and coolers have been indicated as they are in common use and are often built by the factories. However, there are very efficient rotary cookers and coolers on the market that may be installed if they are available at an attractive price. With the rotary cookers and coolers the cans progress on a spiral through the machine and thus do not require unscrambling. With the draper belt cooker and cooler an unscrambler 20, Figure 10, is necessary. This process is necessary when *Bacillus thermoacidurans* is present.

When the "high temperature short time" process is used the juice is heated in a heat exchanger to 250° F. for 42 seconds and rapidly cooled to 190-200° F. before filling. It is sealed, held 3 minutes and rapidly cooled.

After the cans fall out of the end of the unscrambler they are on a belt 21, which elevates them usually to the ceiling of the warehouse. They are righted by passing through a can twister and travel on a can track for several hundred feet so that their outside surfaces are dry when they pass through the labelling machine 23, Figure 11. The return end of the can drying track is 22. After the cans pass through the labeller, they roll into a casing machine 24, Figure 12, and are cased. A stitcher staples the bottom of the case. Large operations also use case gluers and sealers as illustrated in Figure 13. If this machine is used, the cases are merely formed and placed on the casing machine. When the case is filled it is placed on the gluer, sealer and former. From this machine the cases are placed on pallets, and palletized in the warehouse ready

for shipment. If the company is not in a position to label the cans immediately, then the labeller is omitted and the cans passed directly from the drying track into the casing machine and cased bright.

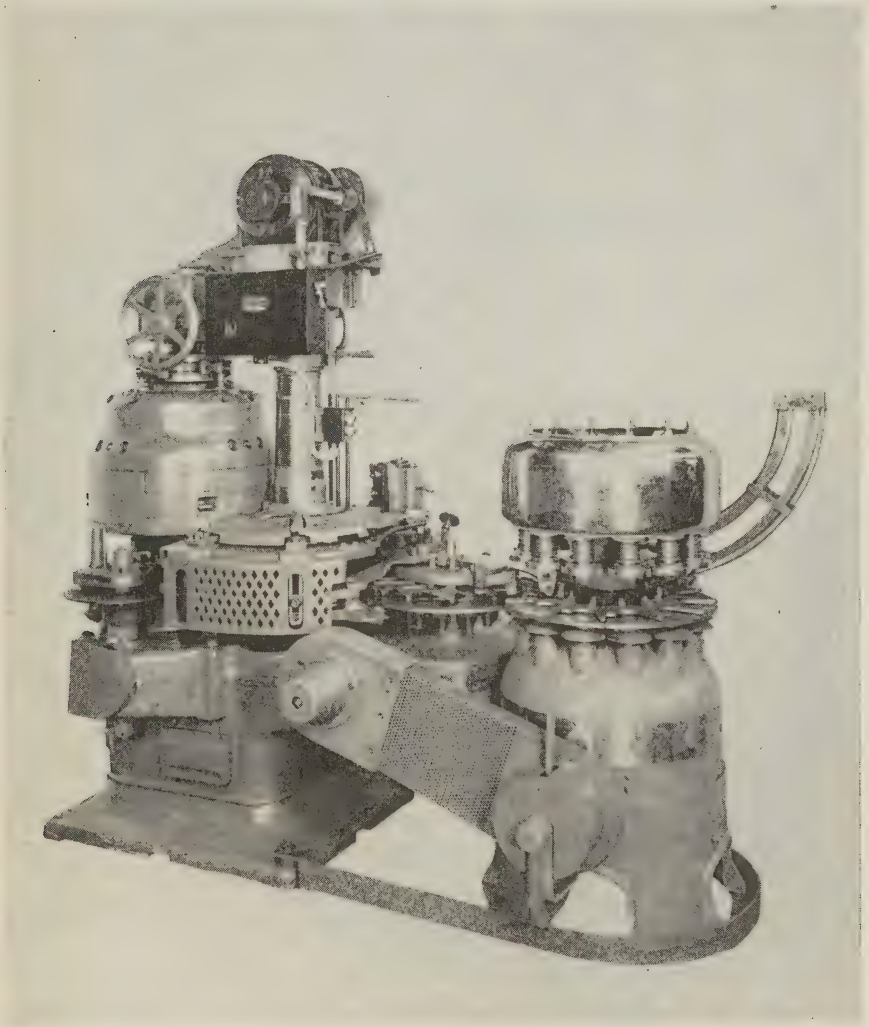


FIG. 8. Rear View of a Close Hook-up of High Speed Capper and 12 Valve Filler

This line permits high speed operation with a minimum of supervision. However, it must be pointed out that there are plants making satisfactory juice in which the juice is accumulated in 100-gallon tanks. This juice must have been previously extracted at 190° F. In the 100-gallon tanks it is salted, heated and delivered to the filling machine. In this case, the juice is in the tank for a few minutes only. Experiments have shown that no significant loss in quality or vitamin content occurs if the holding period does not exceed 10 minutes. It has also been shown that where tomato juice is manufactured under proper conditions, the loss of vitamin content should be not more than 2 to 3 milligrams (mg.) per 100 milliliters (ml.) of juice. Where small holding tanks are

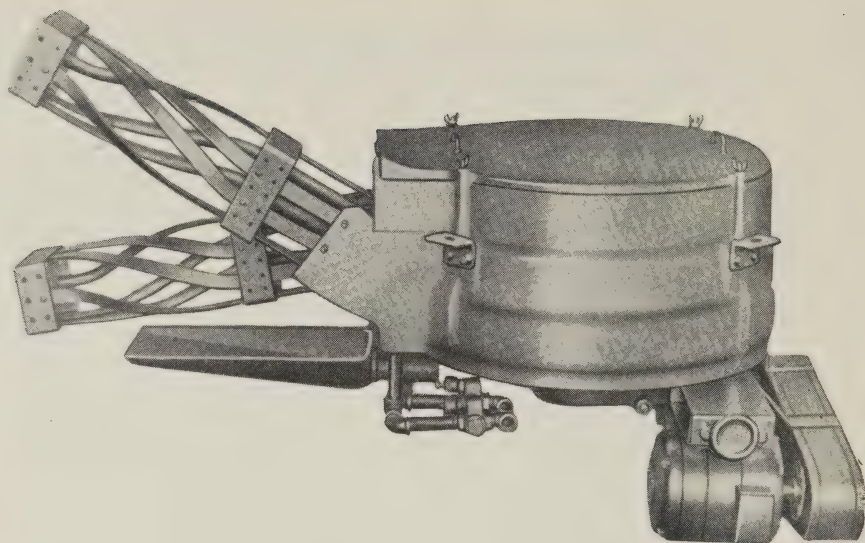


FIG. 9. Empty Can Washer

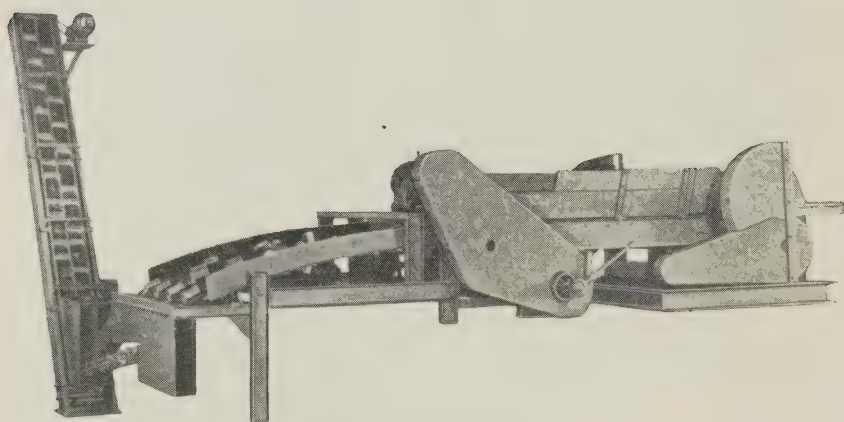


FIG. 10. Can Unscrambler

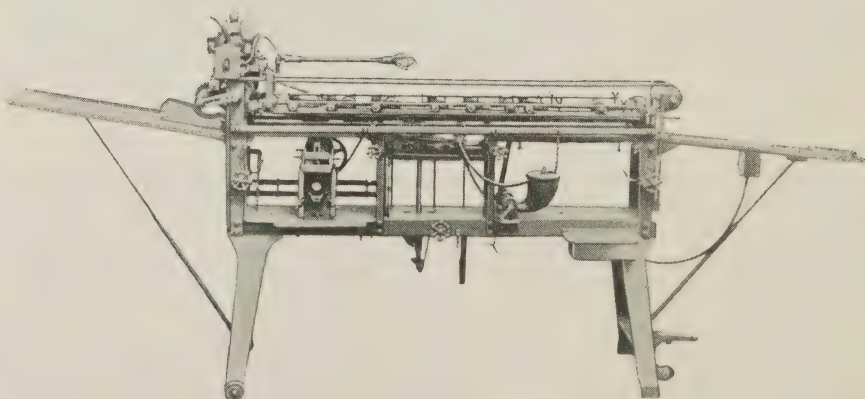


FIG. 11. Labelling Machine

used this retention has been possible. However, where large tanks are used to accumulate juice for periods of half an hour, this retention is not possible.

There is some correlation between the retention of ascorbic acid and quality (24, 44). There is a definite correlation between ascorbic acid content of the final product and the equipment and processing technique (see page 48). Consequently an effort is being made to include an ascorbic acid assay as a factor in grading commercially canned tomato juice.

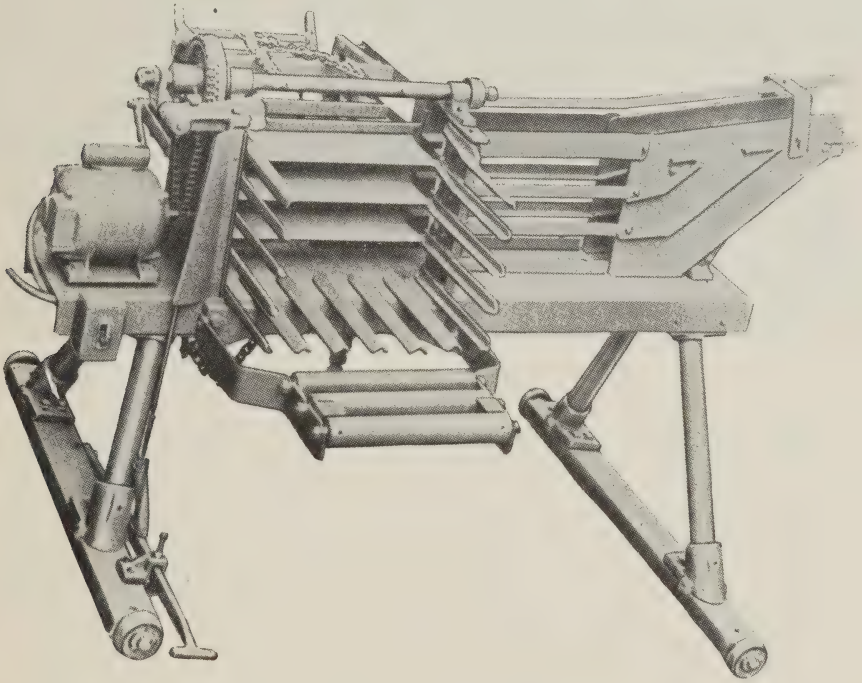


FIG. 12. Casing Machine

EQUIPMENT

There are three points that may be considered under this heading. First, the equipment should be capable of being cleaned easily. Secondly, it should be of a type that allows continuous operation so that as much as possible of the nutritive value of the tomato can be retained. Thirdly, it should be economical to operate.

As all tomato juice produced in Canada for inter-provincial shipment is required to pass minimum mould count requirements, the design of equipment that can be easily cleaned and kept clean is very important. All the items indicated in the drawing by the numbers 1, 2, 3, 4 and 5 are for washing the tomatoes. No. 5 which is a rotary washer can be especially effective if water under a sufficiently high pressure is used to remove the soft decaying tomatoes. This pressure is about 125 pounds per square inch. The roller trimming belt is 24 inches wide and 20 feet long. The rollers may be made of any of the resistant white metals such as stainless steel or aluminum. Whatever the material it should be built on a stand so that it can be thoroughly cleaned between shifts.

The preheater 9 shown is one with stainless steel or nickel tubes. The milled tomato or extracted tomato juice passes through these tubes. Care

should be taken to see that the tubes are always bright and do not become encrusted with baked-on tomato solids. This piece of equipment in particular should be built so it can be quickly and thoroughly cleaned. It is automatically controlled to obtain the desired temperature. The reheater 12 is the top part of the preheater and the remarks on construction and cleanliness of the preheater apply also to the reheater.

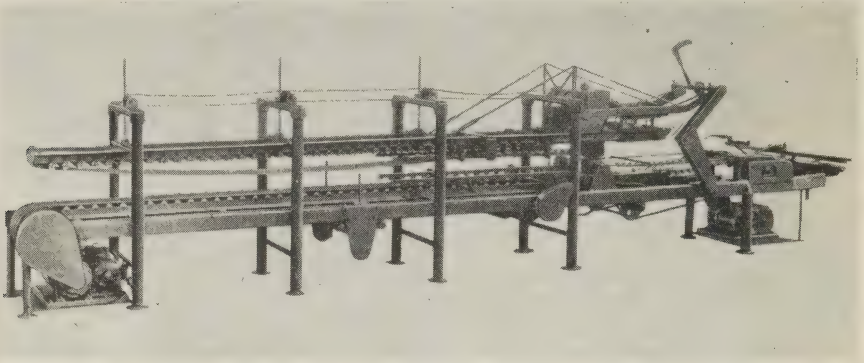


FIG. 13. Automatic Case Former and Sealer

Another feature that aids in standardizing the sterilizing process is the location of a bulb of an automatic control in the bowl of the filler. If the temperature drops too low the whole line is shut off by this control.

A continuous line has been described that has been in common use. It is thought that the inclusion of a cook with this process is valuable insurance. The high temperature short time process may become necessary in Canada if *Bacillus thermoacidurans* becomes well established in tomato districts. If ascorbic acid retention does become a grading factor then equipment will have to be installed that will ensure the maximum retention.

Apple Juice

Most of the commercial apple juice packed in Canada has been the clarified fresh product, sterilized with a flash pasteurizer, and filled hot into enamelled cans, capped and cooled. During the war years it was mandatory that the clarified juice be fortified with ascorbic acid to the extent that a minimum of 35 mg. per 100 ml. would be in the juice whenever it was tested up to 12 months after packing.

The crushed type of apple juice has also been packed in British Columbia. In this juice an effort has been made to preserve the natural colour and flavour of apple flesh and part of the pulp is included so that the final product has from 3 to 10 per cent of suspended or finely ground solids.

Experimental work has been concluded at the Summerland Fruit and Vegetable Products Laboratory on a type of apple juice which is midway between the crushed and the clarified. In this juice, ascorbic acid is sprayed on the apples as they enter the hammer mill. The amount of ascorbic acid used is sufficient to prevent darkening of the juice for at least half an hour. The pulp from the hammer mill is pressed in a conventional hydraulic rack and cloth press and the juice obtained is passed through a deaerator and then through a pasteurizer and into the cans.

The Canadian production figures of canned apple juice from 1940 to 1946 together with dollar values are given in Table 2.

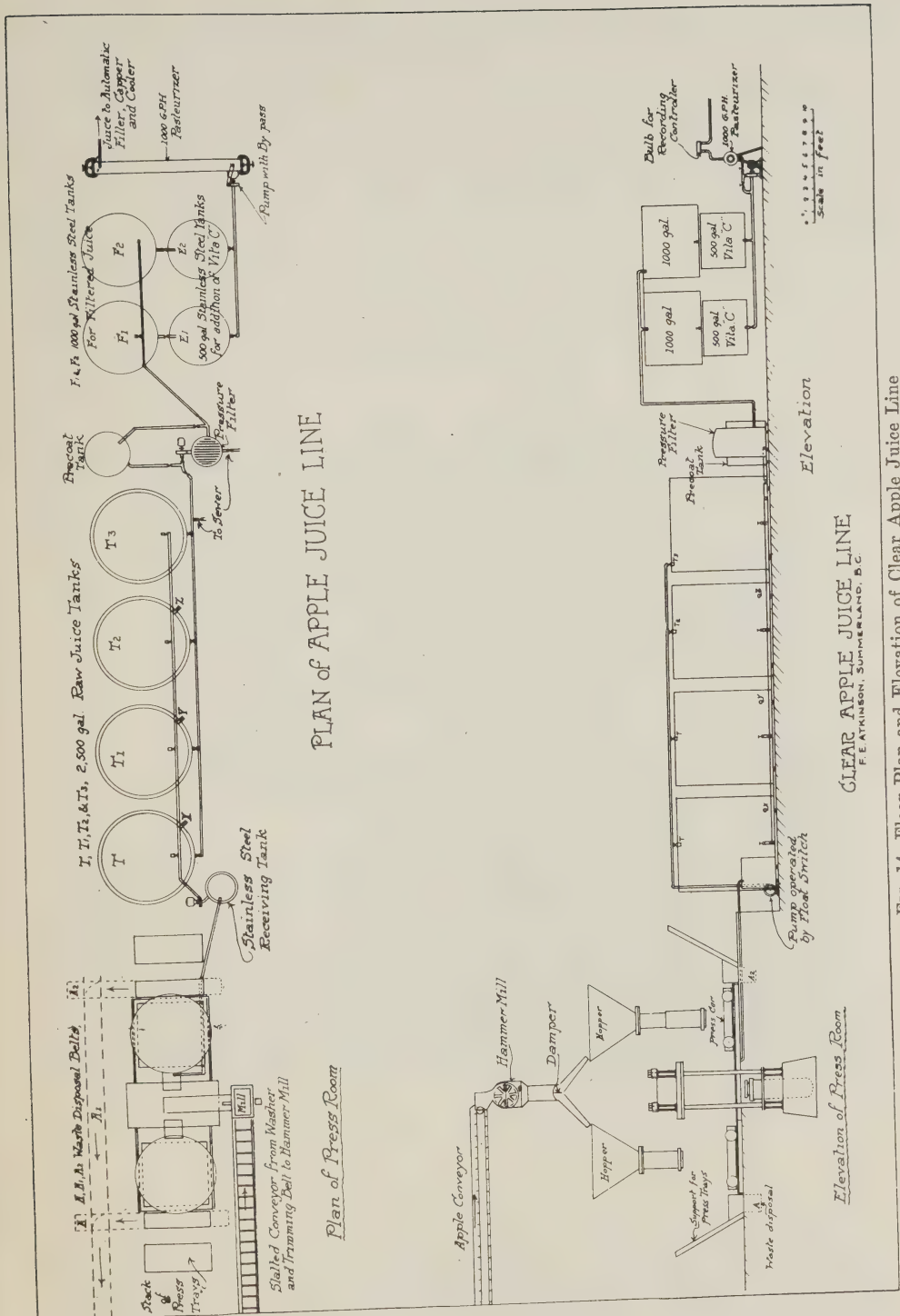


Fig. 14. Floor Plan and Elevation of Clear Apple Juice Line

TABLE 2—CANNED APPLE JUICE

Year	Cases	Value
		\$
1940.....	407,193	650,914
1941.....	405,669	805,693
1942.....	185,977	400,161
1943.....	224,951	722,007
1944.....	401,286	1,293,611
1945.....	154,107	
1946.....	632,488	

The 5-year average from 1940 to 1944 was 325,015 cases of twenty-four 20-ounce cans, valued at \$774,477.

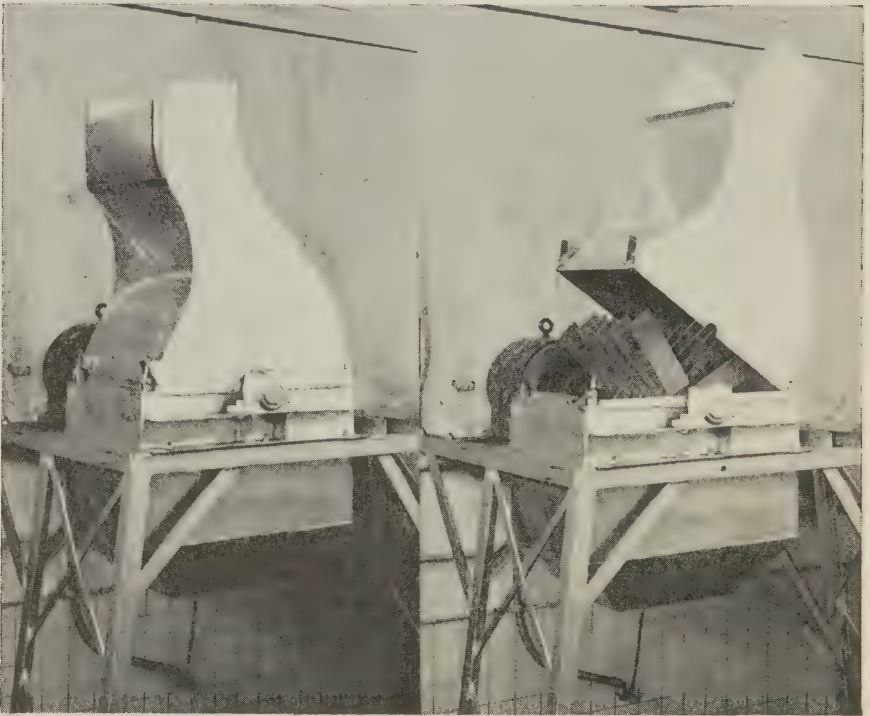


FIG. 15. Stainless Steel Hammer Mill
with Housing Closed

FIG. 16. Stainless Steel Hammer Mill
with Housing Opened to Show
Fixed Hammers.

VARIETIES

Most of the fall and winter varieties are suitable for canned apple juice, that is, either by themselves or in a blend. In British Columbia the juice season starts with McIntosh and as this crop constitutes about one-third of the production, it is natural that a high proportion of the juice is of this variety alone. If the McIntosh apples used are well coloured and at an optimum eating ripe

maturity, the quality of the juice is quite good. On the other hand, poorly coloured apples have less flavour and sugar. Also juice from any over-ripe McIntosh lacks flavour and is extremely mild.

Jonathans also have been found to be very desirable for juicing as well as winter varieties such as Winesap, Stayman and Newtown. Delicious constitutes the variety grown in volume which is not considered suitable for juicing by itself. The resulting juice is too sweet and not sufficiently sprightly. Fifteen to twenty per cent of this variety can be blended with a variety such as Newtown or Winesap to give a juice of high quality. An attractive commercial juice has been made by blending lime juice with Delicious apple juice. Also Hyslop crab-apples have been used to make up the acid deficiency in Delicious juice. In this case, 25 per cent of crabapples and 75 per cent of Delicious gave a satisfactory product. Constituents of several varieties of apples grown commercially in British Columbia, analysed at their optimum state of ripeness for juice manufacture, are given in Table 3.

In Eastern Canada, Arengo-Jones (2) formerly connected with the Fruit and Vegetable Products Laboratory, Central Experimental Farm, Ottawa, states "it has been found that the juice of well ripened McIntosh will supply desirable flavour, and when blended with lightly flavoured juice such as Stark, Spy or Ben Davis, only about 25 per cent is required.

"The juice should not be too sweet nor too heavy in body. Astringency is of less importance than the correct sugar-acid balance, though it should not be above 0.1 per cent.

"The following is a list of apples and blends that have been used at Ottawa:

"*Ribston*.—If pressed when fully ripe, Ribston makes a good juice. The flavour is not strong but very fruity. It may be blended with Wealthy, King or Greening.

"*Stark*.—The juice from this apple does not carry much flavour, but being neutral in flavour and low in acidity it blends well with early picked McIntosh and Baldwin. Some very good juice has been made with Stark alone when the acidity was above 0.5 per cent.

"*Baldwin*.—This juice carries a rich flavour when the fruit is ripe. The acidity varies considerably, but at an acidity of not over 0.55 per cent the juice is good without blending. During December, about 10 per cent McIntosh should be added. After December the juice is very liable to be 'musty' due to the apples moulding at the core.

"*Spy*.—Until ripe this apple yields a juice which is generally quite acid and with not much flavour. It blends very well with McIntosh using about 25 per cent of the latter. When ripe, no blending is required.

"*Golden Russett*.—This apple is very popular in the United States where the heaviness of the juice is appreciated. For a rich aromatically flavoured juice it may be blended with Spy 1 to 1 or the addition of a little McIntosh juice will provide more apple flavour.

"*McIntosh*.—The juice of this apple grown in Ontario and Quebec is extremely valuable for blending and the flavour is very stable in the bottled product. Used alone the flavour is sometimes too strong and it ages to almost a 'perfumed' flavour. It may be blended with any of the winter varieties, 25 per cent being the maximum amount necessary to add. Until the acidity drops below 0.45 per cent, McIntosh may be used alone.

TABLE 3—COMPOSITION OF APPLES GROWN IN BRITISH COLUMBIA (1943-45) AND ANALYSED AT OPTIMUM RIPENESS FOR JUICE MANUFACTURE

Variety	Constituents per cent by weight						Tannin**
	Soluble* solids	pH	Total acid (Malic)	Sugar as invert			
				Total	Reducing	Sucrose	
	%		%	%	%	%	%
Delicious—							
Average.....	13.16	3.91	0.27	11.79	8.81	2.89	0.0261
Maximum.....	13.90	4.08	0.58	12.65	10.13	3.52	0.0329
Minimum.....	12.31	3.78	0.20	10.92	8.28	2.10	0.0212
No. of samples.....	14	11	19	19	10	10	5
Golden Delicious—							
Average.....	14.26	3.60	0.41	12.39	7.86	3.78	0.0275
Maximum.....	15.74	3.72	0.51	13.31	7.97	5.34	0.0364
Minimum.....	13.20	3.48	0.32	11.60	7.75	2.21	0.0235
No. of samples.....	4	4	4	4	2	2	3
Jonathan—							
Average.....	13.56	3.33	0.64	11.45	8.29	2.97	0.0233
Maximum.....	14.87	3.40	0.74	12.33	8.91	3.49	0.0329
Minimum.....	11.91	3.27	0.48	10.46	7.97	2.36	0.0134
No. of samples.....	7	9	9	9	7	7	5
Jubilee—							
Average.....	14.94	3.53	0.40	12.60	8.02	3.90	0.0341
Maximum.....	17.22	3.64	0.49	14.02	8.26	3.90	.....
Minimum.....	13.20	3.41	0.34	11.57	7.78	3.89	.....
No. of samples.....	3	3	3	3	2	2	.....
McIntosh—							
Average.....	12.72	3.35	0.54	10.89	8.30	2.61	0.0375
Maximum.....	15.59	3.51	0.74	13.17	10.15	3.61	0.0625
Minimum.....	11.82	3.18	0.33	9.60	7.22	1.47	0.0138
No. of samples.....	10	22	22	22	16	16	7
Newtown—							
Average.....	13.76	3.31	0.61	11.67	7.50	4.18	0.0169
Maximum.....	14.24	3.46	0.68	11.99	7.82	4.37	.....
Minimum.....	12.82	3.15	0.50	11.46	7.09	3.88	.....
No. of samples.....	5	5	5	5	4	4	.....
Stayman—							
Average.....	13.81	3.37	0.59	11.69	7.05	5.02	0.0236
Maximum.....	14.34	3.42	0.62	12.07	.....	.....	.....
Minimum.....	12.94	3.30	0.52	11.17	.....	.....	.....
No. of samples.....	3	3	3	3	1	1	.....
Winesap.....	14.83	3.47	0.58	12.82	10.67	3.14	0.0271
Wealthy.....	11.90	3.10	0.84	9.85	8.06	1.72	0.0230

* By refractometer.

** Determined by method of Hartmann, B. G. Jour. Assoc. Off. Agr. Chem. 26: 452-462. 1943.

"Melba.—The juice of this variety when in prime 'eating-ripe' condition makes an excellent grade of juice and is highly recommended.

"Wealthy.—Requires blending with McIntosh.

"Snow.—Blends well with McIntosh."

Marshall (28) reported that for Michigan a typical blend of some of the juices having the best quality would be: Northern Spy 20 to 40 per cent;

Grimes Golden 10 to 20 per cent; Baldwin 10 to 30 per cent; and 10 to 20 per cent of one or more of such varieties as Stayman, McIntosh, Delicious, or Rhode Island Greening. He also considered that Jonathan may be blended with three or four of the other important commercial varieties. His observations indicate that any of four or five commercial varieties that are available in a fully ripened condition after early October may be used to make a satisfactory blend of juice.

Regardless of the variety, the apples used in juice should be in a prime eating condition and although they may be culls due to insect injury or blemishes, they should be of a quality that has the flavour of the variety well developed.

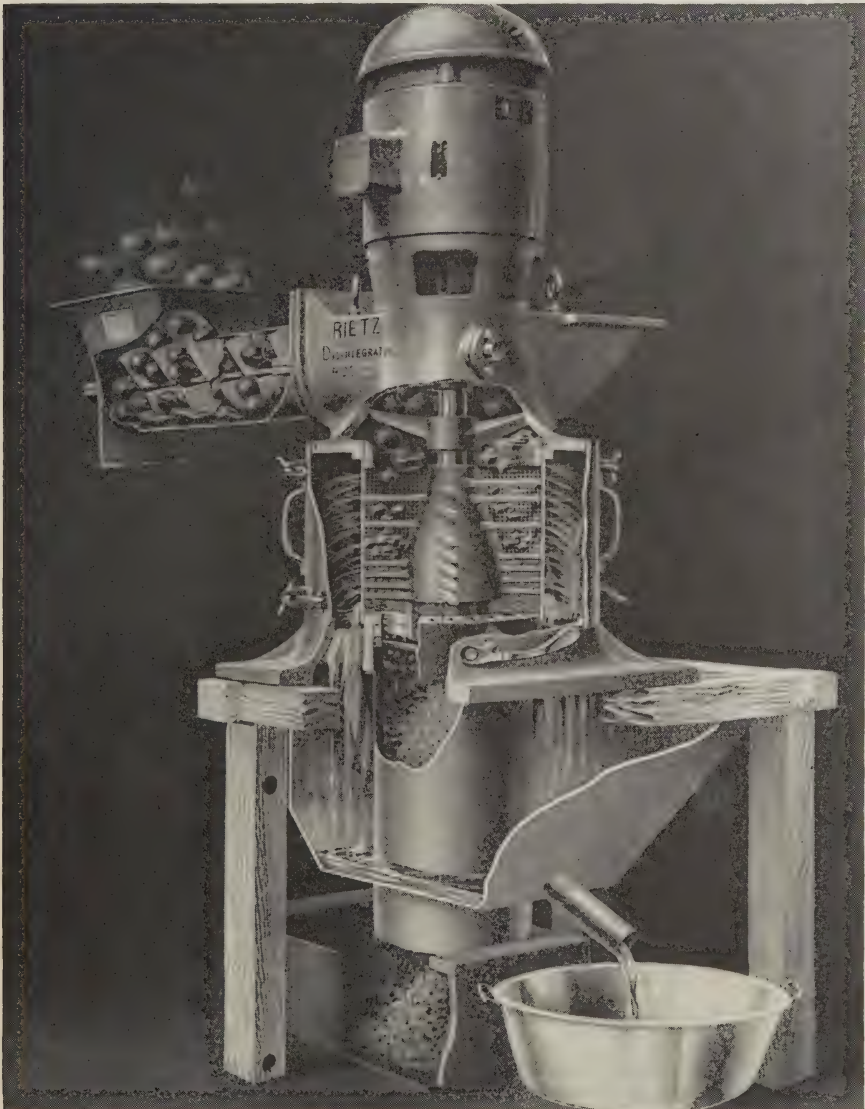


FIG. 17. Cut-Away Photograph of Rietz Disintegrator

GRADES

Choice quality apple juice must have a specific gravity of not less than 1.045 when tested by hydrometer and an acidity of not less than 0.4 and not more than 0.65 per cent malic by volume. Juices with a higher acid content are marked "sharp" or "acid type". The specifications for Fancy quality apple juice are similar except that the juice must have a specific gravity of not less than 1.050.



FIG. 18. Cylindrical Filter with Precoat Tank

PROCESS

Clarified

In Figure 14, a floor plan and elevation of a clear apple juice line is depicted. The starting point at the washer and trimming belt is not shown. However, the washer should be of a type in which 1 per cent hydrochloric acid can be flooded over the fruit at a temperature approximating 130° F. This wash may slightly crack the skins but as the apples are to be ground shortly

after they leave the washer, this injury is unimportant. The acid wash is followed by a cold fresh water wash. After washing, the apples pass over a trimming belt where defects are cut away.

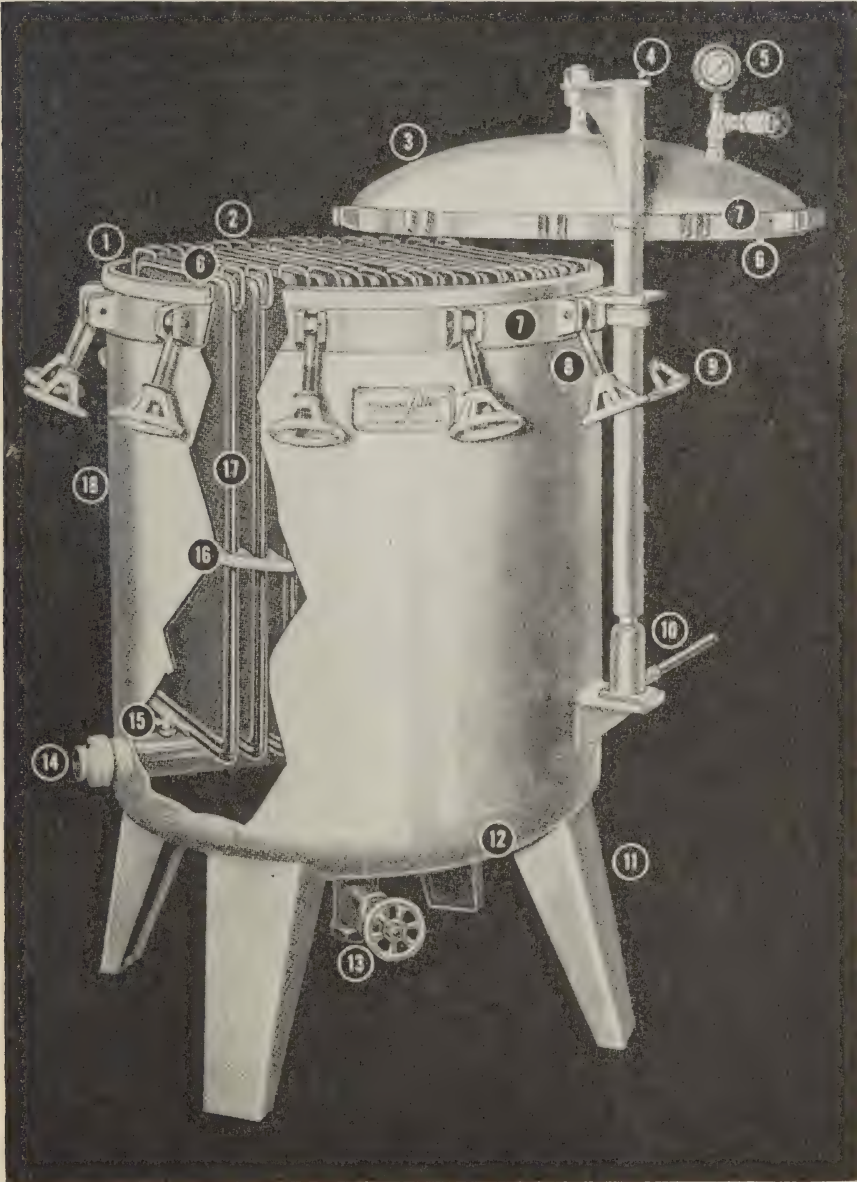


FIG. 19. Cut-Away of Cylindrical Pressure Filter: (1) Machined cover-gasket bearing surface; (2) Leaf handles; (3) One-piece seamless dished-head cover; (4) Cover lift beam; (5) Vent gauge assembly; (6) Machined cover gasket groove; (7) Heavy reinforcing rings; (8) Forged steel eyebolts; (9) Heavy handwheels; (10) Hydraulic cover lift; (11) Formed support legs; (12) One-piece seamless dished-head bottom; (13) Combination inlet and drain; (14) Filtrate manifold outlet; (15) Cast leaf nozzles; (16) Slotted leaf-spacer bars; (17) Tubular leaf frames; and (18) Welded tank shell.

The drawing starts with a slatted conveyor delivering apples to a hammer mill. (See also Figures 15 and 16.) This mill is a fixed hammer type made of stainless steel bars with the housing also of stainless steel. Various sized screens may be used, depending on the firmness of the apples. (Rietz disintegrators, Figure 17, are being used in some American factories and are being investigated for Canadian use.) From the hammer mill the pulp falls through chutes to one of two hoppers. In these hoppers the pulp accumulates and is fed onto press cloths on press trays from the telescoping chute at the bottom of the hopper. This chute also contains a damper.*

The press room arrangement suggested in this drawing is called the "in and out" arrangement. Each car moves from under the loading chute onto the hydraulic press and is pressed and then moved back under the loading chute. While one carload of cheeses is being pressed, the other car is unloaded and reloaded. As the press cloths are removed from the trays they are shaken over the waste disposal belts shown as A and A2. The press trays are leaned against the supports for this equipment while additional supports may be provided for the press cloths. The waste carried by belts A and A2 is deposited on belt A1 and may be taken to a hopper outside the building, from whence it may be hauled by trucks or used in other processes.

The juice obtained by pressing, flows through a stainless steel pipe to a receiving tank. This tank is equipped with a float-operated switch to start and stop the pump motor. This pump delivers the juice to tanks shown as T, T1 and T2. Each of these tanks has a capacity of 2,500 gallons and is equipped with a heating coil to aid in clarification. T3 is reserved for partially clarified juice. Partial clarification is obtained with either enzyme preparations, tannin and gelatin, or a combination of the two. A portable pump is indicated in the drawing. A suction line from this pump would be connected to tanks at X, Y and Z and the partially clarified juice pumped to tank T3. Further information on the use of clarifying agents is given on pages 31 and 32.

The juice from T3 is pumped through the cylindrical pressure filter, Figures 18 and 19, and delivered to 1,000-gallon tanks marked F1 and F2. These tanks are for holding the juice before it is pasteurized. If, however, the juice is to be fortified, it is run by gravity from the 1,000-gallon tanks to tanks E1 and E2 which are 500 gallons in size and in which tanks ascorbic acid is added. It has been found that in the addition of ascorbic acid the batch of juice should be one that can be run through the pasteurizer in not more than half an hour. In this case, a 1,000-gallon-per-hour pasteurizer is indicated so that 500 gallons is a half-hour batch.

The juice from either the 1,000-gallon or 500-gallon tank is pumped to a cylindrical pasteurizer, Figures 20 and 21, and heated in about 11 seconds to 190° F. This pasteurizer was developed by the Fruit and Vegetable Products Laboratory at Summerland, B.C., and is in general use in the apple juice factories of British Columbia. There are, however, many other types of pasteurizers that are satisfactory for apple juice. The nickel alloy pump supplying the juice to the pasteurizer is equipped with a by-pass so that the temperature can be roughly adjusted by hand. An automatic control on the steam supply to the pasteurizer effects the remainder of the regulation. From the pasteurizer the juice flows to an automatic filler and from there to a capper and cooler. Originally it was suggested that a 2-minute holding period follow the closing of the cans. However, commercial practice has been to cool immediately after capping. The can in general use for clarified juice is made of Type L steel plate with a 1.5 per cent tin coating and fruit enamel lining. As with tomato juice a speed of 125 to 225 cans per minute requires a special transfer

* A new method involves the use of a 6-inch stainless steel pipe with a ball joint under the hammer mill. This pipe has a sliding gate to regulate flow and is counter-balanced. It is a quick and sanitary method of delivering the pulp to the trays.

between filler and capper to prevent undue spillage. Here again the same situation is true as in the case of tomato juice that the less headspace when the can is capped, the higher will be the retention of ascorbic acid in fortified apple juice. In other words the loss in ascorbic acid is proportional to the oxygen contained in the headspace.

Crushed

Crushed apple juice is quite different from canned clarified juice in that it contains fine cellular material and the manufacturer endeavours to keep the product from oxidizing and developing grey or darker colours. It has been advertised as "liquid apple" and this in a sense is a true statement. If the juice is properly made, one can determine the variety by the aroma and flavour of the juice. The colour is also the natural colour of the apple flesh.

In its manufacture the apples are washed and trimmed in a manner similar to that employed in the manufacture of clarified juice but instead of passing through a hammer mill the apples pass through a rough slicer which cuts them into thick slices. The slices then fall into a Schwartz comminuter extractor which is the heart of the process. This is a vertical mill which grinds the apples and forces the fine particles and juice through special rubber screens. These screens are made of hard rubber and are perforated with holes which vary in number from 1,600 to 3,600 to the square inch. The Schwartz machine has very fine clearances and can be regulated to give the desired amount of suspended solids. The amount of suspended solids now considered best is between 3 and 10 per cent. The machine is rented on a fixed charge per case (royalty basis). The juice is drawn from the extractor by a vacuum line which delivers the juice to the deaerator. In this particular case a deaerator with horizontal shallow pans has been used with a vacuum of 29.4 inches. From the deaerator the juice is pumped with a turbine type stainless steel pump. In order to make the work of this pump as easy as possible the deaerator is located several feet higher than the pump. The pump delivers the juice to a homogenizer and thence to a pasteurizer. In the pasteurizer the juice is heated to 190° F. and delivered to an automatic filling machine. From then on the process is the same as for clarified juice. Under ideal conditions, plain cans can be used for this type of juice.

Natural—Juice Maintained in Natural State by Ascorbic Acid.

In clarified juice, oxidation occurs. During oxidation of the juice, a brown or amber colour and a characteristic flavour develop. This flavour is not the flavour of fresh apple. Furthermore, filtering removes part of the flavour. Thus in a clarified juice, one can have a maximum eye appeal and a flavour that is not typical of any variety.

On the other hand, in crushed apple juice the fresh fruit flavour can be very good but the eye appeal is not strong and many do not like the particles or suspended solids in this juice. As a compromise between these two, experiments have been conducted and samples packed in order to obtain the reaction of the commercial trade to a new type juice that retains the natural colour and flavour, and which is opalescent in appearance. For want of a better word, this juice has been called "natural" apple juice as it is thought that this juice is as close to the natural contents of the apple as anything that has yet been produced. This is a similar idea to that recently reported by C. S. Pedersen (33 and 34). However, additional information has been obtained on suitability of varieties and adaptation of the process to commercial conditions.

In its manufacture, the apples are sprayed with ascorbic acid as they enter the hammer mill. The pulp is pressed in a hydraulic press with racks and cloths. The resulting juice is strained, deaerated if desired, pasteurized, and passed into the filler. The remainder of the process is the same as for clear juice.

The amount of ascorbic acid required in milling has to be previously determined. To avoid dilution, the ascorbic acid for spraying should be dissolved in previously pasteurized and cooled juice. The volume of spray may be varied, satisfactory results being obtained with amounts around 150 ml. for each 33 pounds of fruit. It has been found with apples of the McIntosh variety that are still crisp and at firm eating ripe maturity, that 20 mg. of ascorbic acid per 100 g. of fruit will give a residue of 1 mg. in the juice after it is pressed. If 1 mg. is present, then this juice can be held for periods up to half an hour before being deaerated and pasteurized. Jonathan apples in over-ripe condition required 35 mg. However, in prime eating ripe condition it is expected they would require an amount similar to McIntosh in good condition. Satisfactory products have also been made from Winesap and Stayman varieties. So far, it does not appear that this process can be used economically with varieties containing a large amount of oxidative enzymes, such as Newtown, Rome Beauty or Delicious, nor can it be used with any varieties that are past their prime eating maturity. However, for varieties such as McIntosh, which have a mild but delicate flavour, it is thought that this type of juice offers considerable promise.

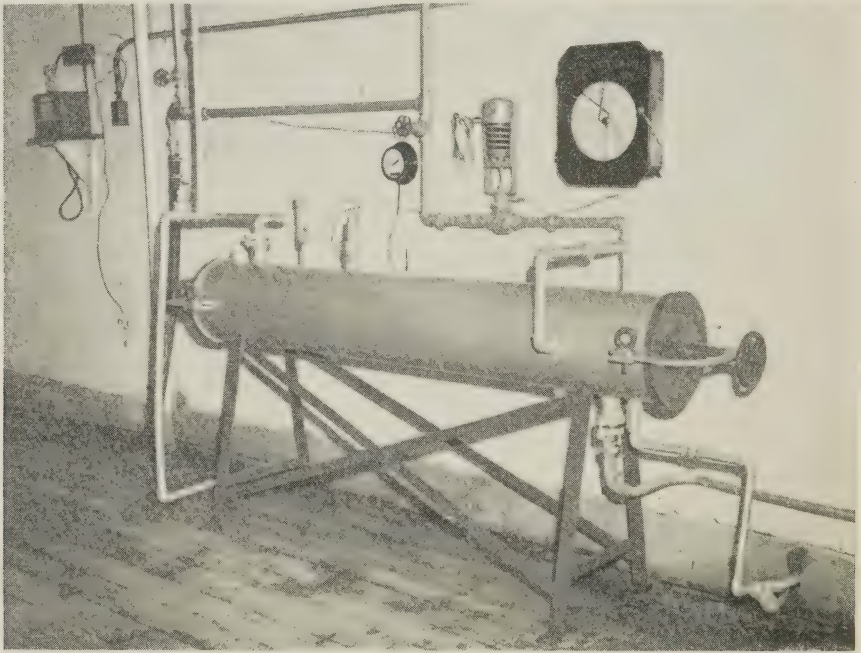


FIG. 20. A Cylindrical Pasteurizer

It is interesting to note also, that by the use of ascorbic acid in this product, a precipitation of colloids is prevented and the opalescent characteristic is maintained. In centrifuging, at 3,300 revolutions per minute (r.p.m.) for 5 minutes, only 0.3 per cent of solids was obtained. In samples that have been incubated at 50-75° F. for 4 months, additional precipitate has accumulated just as precipitate accumulates in orange or grapefruit juice; but this is quickly dissipated into the juice upon shaking.

Individuals who have tasted this juice have rated it very good. The reaction of the trade to semi-commercial samples has also been favourable. A 100,000-case introductory commercial pack was put up in 1948. Much of the

success of the pack depended on the maintenance of at least 1 mg. of reduced ascorbic acid in the extracted juice and a rapid continuous operation. Fortification with ascorbic acid was an added protection.

EQUIPMENT

Clarified

1. Washer: Apple trees receive a relatively large application of spray during the growing season with the result that spray residues are present on the mature fruit. In addition there is dust, etc., which should be kept from entering the final juice. Consequently it is advisable that the apples pass through an acid bath washer. Fortunately the apples will be made into juice immediately and therefore can receive a much hotter treatment than apples that are intended for fresh marketing and so may need to be stored for several months. One per cent hydrochloric acid at a temperature of 130° F. will generally give an efficient wash. These washers, Figure 22, are usually wooden tanks with a distribution system on top consisting of a wooden flume and plate glass baffles to distribute the acid above the fruit. The apples progress through the machine on a positive wooden conveying system. The acid is pumped with a hard rubber pump and the tank is heated with a stainless steel steam coil. Several commercial washers are on the market.

2. Stainless Steel Hammer Mill: This mill is of the fixed hammer type. The hammers are made of $\frac{1}{2}$ by 2-inch stainless steel bar and are spaced an inch apart on the shaft with stainless steel ferrules. The shaft carrying the fixed hammers revolves at 1,750 r.p.m. and requires 15 horsepower (h.p.) where a capacity of 6 tons per hour is being handled. A half round perforated screen in the bottom of the mill is in a slot so that it is easily removed for cleaning or for changing in size. The perforations in this screen vary from $\frac{3}{8}$ inch up to $\frac{3}{4}$ inch. The size of screen used is determined by the maturity of the fruit being handled. In the early season while the apples are hard and crisp, the $\frac{3}{8}$ inch screen is used while the larger screens are used with more mature apples. A stainless steel hammer mill is preferred to a grater as it has large capacity, is easy to clean, and grinds the apples to a more even-sized pulp. However, the Rietz disintegrator is proving popular in Californian factories and may be tried in British Columbia plants in 1949.

3. Hydraulic Press and Press Room: The size of press indicated in Figure 14 is one with an 18-inch ram and 60-inch racks. The ram of this size should be capable of developing 318 tons total pressure with 2,500 p.s.i. on the pump. In order to aid sanitation in the press room, nylon cloths are being introduced while plastic racks may replace wood. The wooden collecting trays are being covered with stainless steel. The press room is very often poorly arranged and because of the arrangement is much too difficult to clean. Consequently it is often in an insanitary condition. The arrangement suggested in the drawing is probably the simplest for efficient large-scale operation. If the floors and walls are made of suitable acid-resistant material that is easily cleaned, it should be possible to keep the whole room in an acceptable sanitary condition.

4. Piping: From the press to the various items of equipment and to the filler, stainless steel piping and equipment has been indicated. It is not necessary that this equipment should be stainless steel but it should be a nickel bearing alloy without a high copper content, or glass, or hard rubber. It is necessary to avoid copper as small amounts such as 46 parts per billion have been shown to have a destructive effect on ascorbic acid. All the piping should be connected with sanitary joints that can be quickly dismantled so that the lines can be thoroughly cleaned.

5. Tanks: Wooden tanks are shown in the drawing for reasons of economy. If money were available these would also be made of stainless steel or some

similar resistant metal. Each of the first three tanks, that is, T, T1 and T2, should be equipped with a stainless steel heating coil so that the most efficient temperature may be obtained during clarification.

JUICE STERILIZER

Scale 1" = 1'0"

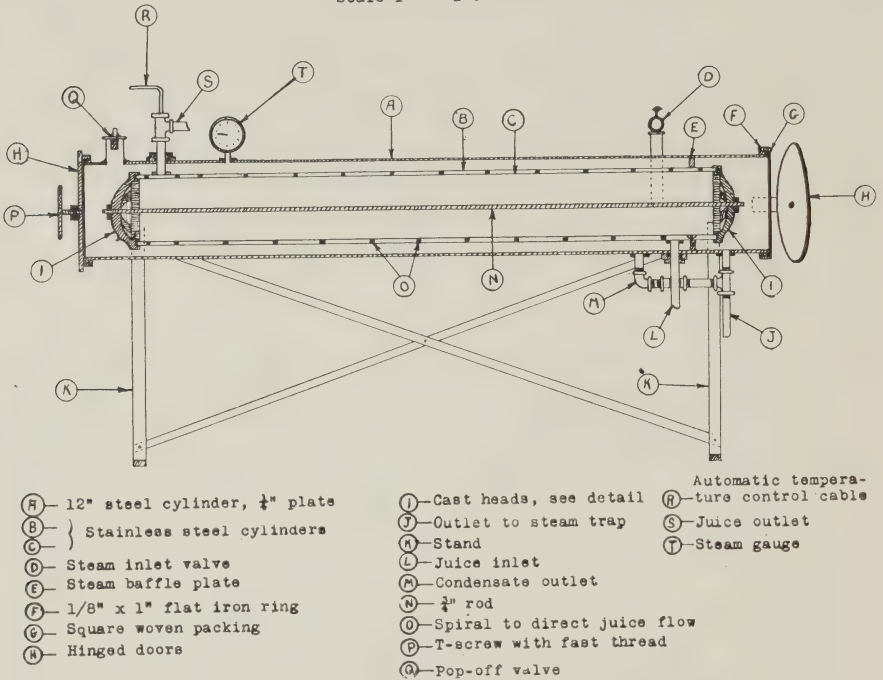


Fig. 21. Longitudinal Section of Cylindrical Juice Pasteurizer

6. Pressure Filter: A round pressure filter is indicated equipped with filter plates covered with stainless steel cloth. There are three especially good features in this filter. First, the cylindrical shape with a heavy reinforced removable head makes possible the use of high pressures without leakage, thus ensuring large capacity. Secondly, it is of all-metal construction so that it can be kept in a sanitary condition. Thirdly, the stainless steel woven cloth is much easier to handle from a maintenance standpoint than cotton filter cloth. The stainless steel cloth does not shrink, is easy to keep in place, and is not a breeding ground for organisms.

7. Pasteurizer. The pasteurizer on the apple juice line drawing is shown in more detail in Figure 21. This illustrates a pasteurizer in which two stainless steel cylinders, 6 feet long, have been placed inside one another, the ends sealed with brass castings and rubber gaskets, and provision made for juice to flow between the cylinders. These cylinders are located inside a 12-inch steel tube equipped with ends which can be quickly opened. Steam enters at the outside near one end, flows along the outer stainless steel cylinder and thence down the inside of the inside cylinder. With a steam pressure of 5 pounds, about 440 gallons of juice an hour can be heated from 40° F. to 186° F. These sterilizers have been in general use in the apple juice industry of British Columbia for several years. They are built in various sizes to accommodate the anticipated capacity of a plant. They are controlled by regulating the by-pass on the pump

supplying the pasteurizer with juice and by a self-activated control whose bulb is in the juice line flowing from the pasteurizer and which control activates the valve on the steam supply to the pasteurizer.

There are several commercially built pasteurizers that are very satisfactory. The one described for tomato juice is believed to be one of the better types.

Crushed

The equipment for washing and trimming apples for crushed type juice up to the point where they are milled, is the same as in a clarified juice factory. From this point, in the crushed juice factory, however, there are some differences in equipment. These differences include a rough slicer to cut the apples into about one-inch slices, a Schwartz comminuter-extractor, and a deaerator. The slicer is merely to get the apples cut up into large pieces that are easier for the Schwartz comminuter-extractor to handle. This machine grinds the apples to a very fine pulp and extracts the juice. The part where the juice accumulates is sealed to prevent entry of outside air and is directly connected with stainless steel tubing to the deaerator. Accordingly only a few seconds after the juice is extracted from the apple pulp it enters the deaerator.

The function of the deaerator is to remove the dissolved gases in the juice, especially the oxygen. It is claimed with crushed juice that a vacuum of 29.4 inches in the deaerator is necessary to preserve a desirable colour and flavour. Because of this high vacuum, trouble is encountered from foaming and this has necessitated trial of several types of systems for distributing the juice in the deaerator in a thin film. It is not known if a deaerator as described in the equipment for natural apple juice (see page 30) would be suitable for the crushed type. In this latter deaerator a shaft passes through the top of the deaerator in a special gland. This has been operated with a vacuum of 28.5 inches. The maintenance of a vacuum of 29.4 inches requires very efficient equipment, involving a steam jet and barometric leg. A mercury barometer is required to make compensations for variations in barometric pressure.

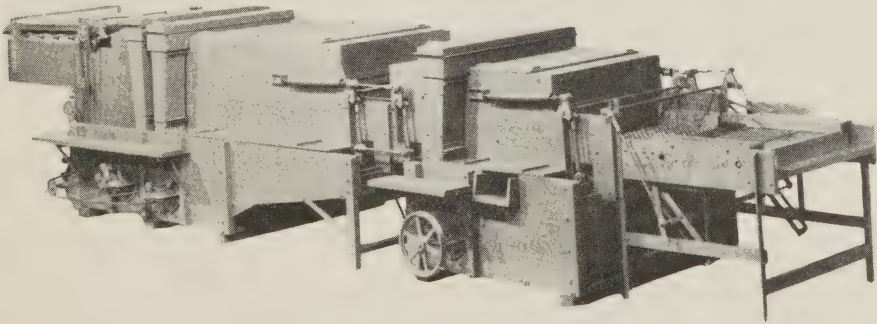


FIG. 22. An Acid Bath Apple Washer

Homogenizer: It has been mentioned in the process for this juice that 3 to 10 per cent of suspended soluble solids is included in the juice. Some have thought that this suspended matter is too granular and that in the granular form it is unattractive to the consumer. Also the particles are usually of sufficient size to settle to the bottom of a glass in a few minutes after processing. Consequently this process now includes a homogenizer that works at about 2,000 lb. pressure and completely breaks up the small particles of apple flesh in the juice. The homogenized juice although containing the same amount of suspended solids is so smooth that no particles can be detected on the tongue and the particles remain in suspension for long periods. There is, however, still a dis-

advantage from an eye appeal standpoint in the fact that the tiny particles that remain continue to cling to the walls of a glass and may be considered unattractive from this angle.

If a homogenizer is to be included in the equipment for crushed juice then it does not appear that the expensive Schwartz equipment is needed as the disintegrator. A crushed type of juice has been made in the Summerland Fruit and Vegetable Products Laboratory by using a conventional apple juice hammer mill for crushing the apples and passing the pulp through an expeller-extractor as used in tomato juice manufacture. This juice was passed through the deaerator, through a homogenizer, pasteurizer, filled into cans, capped and cooled. The yield by this method with McIntosh apples was 35 to 40 per cent. The residue when pressed in a hydraulic press produced sufficient clear juice so that the total yield was about 10 per cent greater than if the pressing had only been done to produce clear juice.

Natural

The equipment used for natural apple juice is similar to that for clarified except that a deaerator, strainer and sprayer for ascorbic acid are added and the storage tanks and filters are deleted.

Deaerator: Figure 23 shows the deaerator with a motor at the top with a shaft in a vertical position. This deaerator is patterned after a design of Geo. N. Pulley (37). The vertical shaft passes through a special gland in the top of the deaerator to a point about one-quarter way down the body of the deaerator. At this point a flat, stainless steel disk about 10 inches in diameter is attached to the shaft. There is a protective ring around the perimeter of this disk about an inch high and sloping towards the centre shaft, the angle formed with the disk being about 45 degrees. At the point of this angle, holes are drilled through the protective rim. These holes are about an eighth of an inch in diameter and are spaced an eighth of an inch apart. Thus, as the juice is constantly drawn into the deaerator by the vacuum and deposited on this revolving disk, the centrifugal force throws the juice against the protective ring and the juice is in turn distributed through the one-eighth inch holes to the inside wall of the deaerator. Here it runs down in a thin film which facilitates the removal of dissolved gases. The juice is constantly withdrawn from the deaerator by a stainless steel turbine pump and passed through a pasteurizer. Vacuums varying from 25 to 28.5 inches have given juices of satisfactory colour. This case is not exactly parallel, however, to that of crushed juice, since with the natural juice ascorbic acid has been added to prevent oxidation. Natural type juice has been made without the use of a deaerator but results are more consistent when the deaerator is used and it is thought that it is a good precaution. Deaerated juice is definitely easier to fill as foaming is eliminated.

Strainer: Instead of a filter the new type juice requires only a strainer that will remove large particles. A strainer that is proving satisfactory under commercial conditions contains screens of 20, 40, 60 and 80 mesh.

Sprayer: In experiments, 75 p.s.i. air pressure was used to atomize 150 ml. of ascorbic acid solution in the hammer mill in 30 seconds, while 33 pounds of fruit were being ground. Commercial application would be in proportion to the above.

Of the three juices, the natural type requires the least equipment and is easiest to make with the exception of regulating the amount of ascorbic acid. After its extraction no storage tanks are required. There are no problems of clarifying with tannin and gelatin or enzyme preparations. Also all filtering problems have been removed.

CLARIFICATION

Apple juice may be clarified by one of several methods, such as (a) tannic acid and gelatin to form a flocculent precipitate, (b) pectin-splitting enzymes, (c) a combination of tannin and gelatin and enzyme, (d) centrifuging, and finally filtering. The first three methods can give a relatively clear juice above the sludge which settles out. Usually the treated juice is passed through a filter using diatomaceous earth to ensure the removal of all small particles.

Tannin and Gelatin Clarification

To clarify apple juice with tannic acid (tannin) and gelatin, stock solutions are employed for trial tests. These are used with quart samples of the product to be clarified and are as follows:

1. Tannin: 9.5 g. to 1000 ml. water ($\frac{1}{3}$ oz. to 2 lb. 3 oz.)
2. Gelatin: 21.25 g. to 1000 ml. water ($\frac{3}{4}$ oz. to 2 lb. 3 oz.)

The tannin is easily dissolved in water while the gelatin should be made into a loose mushy form with cold water and then dissolved in boiling water.

If it is desired to preserve these solutions for more than a few days, preservation may be effected by using alcohol to take the place of part of the water. In this case, 200 ml. of 65 O.P. alcohol is used with 800 ml. water.

Trial amounts of these solutions are used per quart as indicated in Table 4. It is important that the tannin be added first and the juice thoroughly stirred. The gelatin is then added in thin streams about the size of the lead in a lead pencil, with vigorous stirring.

TABLE 4—TRIAL AMOUNTS OF TANNIN AND GELATIN SOLUTIONS

Lot number	Trial amounts		Amounts per 100 gal.	
	Tannin (Solution 1)	Gelatin (Solution 2)	Tannin	Gelatin
	ml.	ml.	oz.	oz.
1.....	12	5.0	1.5	1.5
2.....	12	6.6	1.5	2.0
3.....	12	8.3	1.5	2.5
4.....	12	10.0	1.5	3.0
5.....	12	11.6	1.5	3.5
6.....	12	13.3	1.5	4.0
7.....	12	15.0	1.5	4.5
8.....	12	16.6	1.5	5.0
9.....	12	18.3	1.5	5.5
10.....	12	20.0	1.5	6.0

The least amount of gelatin giving the desirable clarification should be selected. Usually only the first four or five sets are necessary but if satisfactory clarification is not obtained with any of these the complete series may be tried. After these trials have been made the equivalents given under the heading "Amounts per 100 gallons" are added to the large batch to be clarified; that is, if No. 3, using 8.3 ml. of gelatin to 12 ml. of tannin was found to give the best clarification, then 2.5 oz. of gelatin and 1.5 oz. of tannin would be used for each 100 gallons of juice. Both solutions would be prepared in water in the same manner as that used for the stock solutions. Only enough water is used to dissolve the tannic acid. The gelatin should not be too thick. For example, if 15 ounces of gelatin are required to a 500-gallon tank of juice, 1 to $1\frac{1}{2}$ gallons

of hot water should be used. The gelatin may also be dissolved in hot juice from the pasteurizer. A heavy flocculent precipitate will appear in a few minutes and will completely settle overnight.

The filter aid may be added to the juice as soon as the flocculent precipitate appears, or the precipitate may be allowed to settle and the clear juice drained from above the precipitate. The simplest method, however, is to add up to 5 pounds of good diatomaceous filter aid for each 100 gallons of juice to be filtered as soon as the coagulum appears. However, if this method is employed, greater filter capacity is required than when the sludge is allowed to settle.

In order to keep the filter aid continuously in suspension so that all juice going to the filter will contain a uniform amount of filter aid, agitators are necessary. Several portable models are on the market which use an extended shaft with a propeller attached to the shaft of an electric motor. Permanent paddles can also be placed in the tanks.

Tannin and gelatin clarification is most suitable when the apples are slightly immature. When they become over-ripe clarification becomes difficult. For a time, processors use heating coils to aid the reaction between the tannin and gelatin. Eventually, however, as the season progresses, the operators change to either a combination of tannin and gelatin with an enzyme, or the enzyme alone.

Enzyme Clarification

With British Columbia varieties the best results are obtained when the juice is heated to 80-85° F. One-tenth of 1 per cent of the enzyme is then added to the tank and the tank thoroughly agitated. Clarification is usually complete in 8 hours.

Tannin and Gelatin and Enzyme Clarification

It is claimed that by using one-half of the tannin and gelatin required for clarification with one-half the amount of the enzyme that would be used if enzyme were the only clarifying agent, juices can be cleared that would be difficult to clarify with either of these agents by itself, (48). It is also claimed that a more compact sediment is obtained so that there is less loss of juice.

Centrifuging

A rough clarification can be obtained with a Super centrifuge. However, with the latest 1946 model with which the authors have had experience, it was thought that the capacity per hour was not sufficiently high considering the cost of the machine. Also the machine required a considerable amount of labour for cleaning and reassembling. Samples of juice that were centrifuged and filtered did not have a significantly better flavour than samples clarified with the tannin-gelatin or enzyme preparations.

Filters

Plate and frame filters have been in common use but they require a great deal of labour, and juice is lost through leakages. The all-metal filters that are now on the market are proving very popular. The advantages of these filters have already been discussed under Apple Juice Equipment, page 28.

FORTIFICATION

The Canadian Meat and Canned Foods Act states as follows:

"The fortification of apple juice with ascorbic acid (vitamin C) is covered by Patent No. 395770. The patent rights have been surrendered to His Majesty. Processors may apply for details of the equipment prerequisite for licensed

use of the patent. Application for license should be certified by the local inspector. The product shall contain not less than 35 mg. of biologically active ascorbic acid per 100 cc. of juice at any time within twelve months of being packed. This shall be determined by the indophenol titration method and be labelled—

‘Contains not less than 35 mg. of Vitamin C per 100 cc.’

The establishment number and the date of packing shall be embossed or labelled on each container.”

In Figure 14, 500-gallon tanks are shown. On page 24, it was explained that fortification with ascorbic acid was performed in these tanks. This is assuming that the bulk juice is to be fortified in which case the crystalline ascorbic acid in the form of fine crystals or powder is added to a tank of juice and the juice gently agitated until the acid is dissolved. Only brief submerged agitation is required.

The overall loss on canning and 12 months’ storage should not exceed 10 mg. of ascorbic acid per 100 ml. of juice. Consequently it should be necessary to fortify to only 45 mg. per 100 ml. or to the rate of $7\frac{1}{4}$ ounces per 100 Imperial gallons. Frequently, however, processors use as much as 8 ounces per 100 gallons of juice which is at the rate of 50 mg. per 100 ml.

A second method of fortifying with ascorbic acid is by adding tablets directly to the can. The loss of acid in this case is less than when fortifying in bulk. However, uniformity between individual tins is often lacking and the cost of the tablets is comparatively high. A further disadvantage is that different sized tablets are required for the different sized cans.

A third method is to dispense concentrated solutions of ascorbic acid directly into the cans just prior to filling. The solute in this case is pasteurized apple juice. This requires additional labour or an expensive dispenser. Retention of ascorbic acid by this method is excellent provided satisfactory fill and pasteurizing conditions are met.

Prevention of oxidation in the juice prior to addition of ascorbic acid (such as in the crushed type and natural juice), reduces the loss of ascorbic acid by several milligrams. Unless an inert gas is used in the headspace, it is essential to fill the cans full. Cooling the cans promptly and thoroughly with subsequent storage at a temperature below 70° F. assists in retaining ascorbic acid, colour and flavour. For further details concerning ascorbic acid fortification of apple juice, reference should be made to the comprehensive studies of Strachan (43) and Johnson (22). Procedures for the fortification of apple juice with ascorbic acid under commercial conditions have also recently been described by manufacturers of ascorbic acid.

Storage of Apples for Juicing

COLD STORAGE

With many of the apples used for juicing being in the so-called cull grade, cold storage cannot be generally recommended for all varieties. In the case of McIntosh where there are frequently stem punctures and other injuries to the skin, the percentage of rots if cold stored may be high and a great deal of labour is required for removing them. On the other hand, winter varieties and late winter varieties such as Newtown, Winesap, and Stayman Winesap can be cold stored to advantage. In this case the cold storage should not continue for too long as apples sometimes take on a cold storage flavour towards the end of the winter months and this flavour is carried into the juice. Consequently if cold storage is used, the apples should be out of it by the end of February.

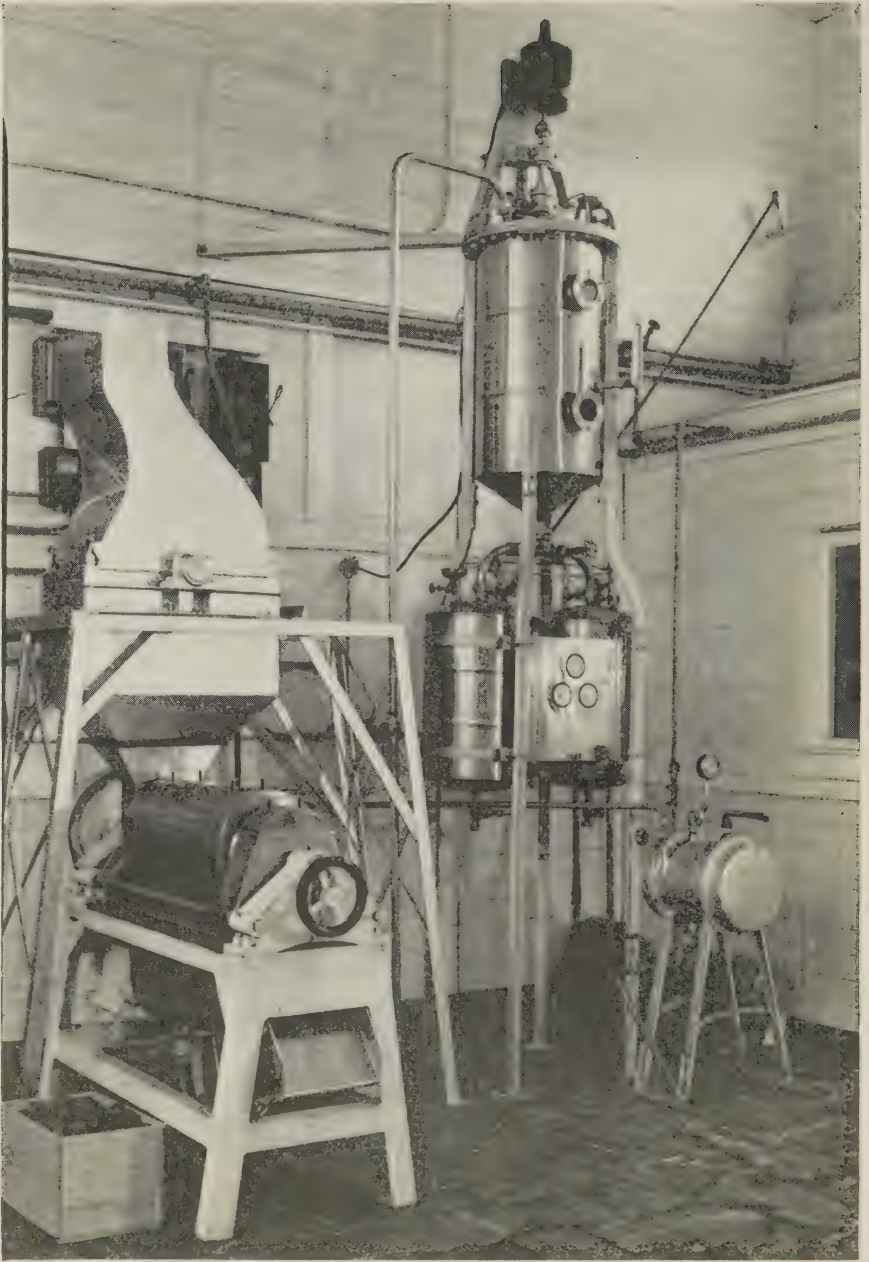


FIG. 23. Deaerator for Juices

COMMON STORAGE

At the peak of apple juice manufacturing during the autumn months, it is a frequent practice to store apples in bulk in bins. (Figure 24.) These bins are best located outside until there is danger from frosts and indoors during the periods of frost. In either case they should have smooth acid-proof floors and

walls that can be thoroughly cleaned. Provision for circulation of cool dry air is desirable. A maximum depth of 4 feet of apples avoids some storage troubles. As water transportation is one of the most efficient and economical methods of delivering apples to the start of the apple juice line it is good practice to have the floors of the bins slope towards a drain immediately outside the bin. Automatic feeding into the drain will be facilitated by opening a hinged section in the bottom part of that side of the bin next to the drain. Spent cooling water from adjacent cold storage plants is often used for this purpose. If water is costly a large proportion can be recirculated.

Apple Juice Concentrate

The product referred to in this section is clarified, depectinized sweet juice concentrated without caramelization to 70 per cent total soluble solids or more. This is not to be confused with the de-acidulated juice that was concentrated during the war to make an apple syrup or so-called apple honey for the tobacco industry. Apple juice concentrate is being used as a (a) reconstituted apple juice, (b) carbonated reconstituted juice, (c) fountain syrup, (d) base for apple jelly, and (e) apple butter. Bakers are also using it in confections. In the United States, the Eastern Regional Research Laboratory of the U.S.D.A. has perfected a process for recovering the esters from the vapours given off during the concentration of apple juice (29). These esters are being returned to the concentrate with the result that the reconstituted juice cannot be distinguished from the fresh juice from which the concentrate was made. These esters are also being added to many of the other products made from concentrates.

Various methods have been used for concentrating apple juice. No doubt the oldest was to boil it in a kettle. Later it was evaporated in shallow pans. Still later, vacuum pans were used for its concentration. With the object of designing a machine that would operate continuously, heat the juice for as short a time as possible, and which would not be too expensive considering its capacity, the Summerland laboratory experimented with a rising-film evaporator. In this machine, juice was pumped into the lower end of a 20-foot 2-inch stainless steel tube. This tube was placed in a vertical position and was surrounded by a steam jacket. At least 75 pounds steam pressure was maintained in this jacket. The juice, as it boiled inside the stainless steel tube, rose higher and higher and, of course, was concentrated as it rose. Finally droplets of syrup and water vapour issued from the top of the tube and were conveyed through a 2-inch bend into a cyclone separator. Here the droplets were gathered on the outside wall of the separator while the water vapour escaped to the atmosphere. The droplets ran down the wall of the separator and thence down a 1-inch fall pipe, and were collected on the same floor level from which the juice had originally started. At the point where the concentrated juice left the machine it passed through a container holding a hydrometer so that the operator could keep a constant check on the degree of concentration. By watching the hydrometer and by having a constant steam supply, the operator knew when and how much to adjust the by-pass on the pump feeding the column. This apparatus proved quite satisfactory and a commercial company has installed a unit handling 5,000 gallons per day. Upon leaving the machine, the concentrate is cooled immediately in order to prevent caramelization of the contained sugar. The time required for concentrating in the experimental equipment was 45 seconds.

Blends of Apple Juice with Lime, Grapefruit, Raspberry and Black Currant

Blends have been prepared of lime, grapefruit, raspberry and black currant juices with apple juice. In each of these blends an effort has been made to improve the apple flavour or develop a new desirable flavour.

When lime juice is used with apple it is desirable to blend it with one of the mild apple juices such as that developed from the Delicious variety. Thus, the lime juice can increase the acidity and only sufficient should be used so that there is a mild lime flavour blended with the Delicious flavour. Experimental packs were tried containing 2 to 6 per cent lime juice. The commercial pack usually contains 2 per cent lime juice. For the commercial pack of this blend, Montserrat lime juice is imported in 40-gallon barrels.

Grapefruit juice has been blended with apple juice in experimental quantities only. However, 20 per cent grapefruit with 80 per cent apple has given a pleasantly flavoured juice.

Raspberry juice for blending with apple is best prepared by freezing the raspberries with 10 per cent sugar and holding in frozen storage until the apple juice season. The juice is then pressed from the raspberries (35) and mixed with apple juice which is ready for pasteurization. The first pressing is cold while for the second pressing the pomace with an equal weight of apple juice is heated to 145° F. At the Summerland laboratory one part of raspberry to three parts of apple juice has given a desirable flavour.

Black currant juice also makes a pleasant blend with apple juice. If undiluted, 15 to 20 per cent gave a product considered better than either juice by itself. Laboratory experiments on extraction at Summerland and Ottawa have favoured two different, although closely related methods. Consequently both are given in the following paragraphs.

For extracting black currant juice a German process was found quite simple and efficient by the Summerland laboratory in 1939. This process consists of heating the fruit in a perforated container in an atmosphere of steam. The fruit is burst by the heat and the juice drips into a lower container. It is best to lay clean, light, factory cotton in the perforated container to prevent pieces of fruit falling into the juice. The top of the fruit should be covered with a light piece of acid-resistant metal to prevent condensed water dripping on the fruit. The layer of fruit should not be more than 6 inches deep. The fruit is heated for 30 to 60 minutes. At the end of this time the finest juice has been obtained but the yield is low. The remainder of the juice available can be obtained by pressing the pulp. The two lots of juice may then be mixed. The amount of sugar added is dependent on the kind of juice. Boskoop black currant juice has sufficient flavour so that it can be diluted with two volumes of water to one of juice. The resulting product should have 15 to 16 per cent soluble solids (mostly sugar). Thus, if this juice is to be canned ready for dilution, it should have a soluble solids content of 45 per cent. This amount can be approximately determined with a Balling hydrometer and should be more accurately checked with a refractometer. One of the simplest ways of using the steam extraction method is in a horizontal canning retort.

Where equipment is not available for steam extraction, the juice may be removed by heating the fruit to 180-185° F. in a kettle, followed by pressing. Small quantities of water are usually added to the fruit to prevent scorching. After pressing, the pulp may be mixed with an equal weight of hot water and pressed again. The two pressings are mixed together, strained, and sweetened as previously described. The steam extraction method is preferred as a better flavour is preserved, the juice is clearer, and extra water is not needed.

Arengo-Jones (1) on the other hand, also writing in 1939, recommended a blanch and press extraction as follows:—

“For juice preparation the currants should be harvested when fully ripe, under-ripe fruit having too much astringency and lacking flavour. A ‘strigger’



FIG. 24. Apples for Juice in Outside Bin Storage

should be used to remove the fruits from the stems as this does not damage them. The cyclone type of machine pulps the fruit and exposes it to rapid oxidation.

"Various methods of juice extraction may be employed but the heat method is preferred at this Laboratory. The fruit may be pulped and immediately heated or to the whole fruit in the kettle may be added a small amount of water (about 20 gallons per ton) and, in either case, heated to 165-170° F. Following a holding period of about 5 minutes the pulp is ready to press. Due to the slimy consistency of this fruit and the large amount of pectin it contains the juice does not press

out readily, but 3 per cent by weight of a coarse filter aid such as Celite 503 thoroughly mixed with the pulp just before pressing will overcome this difficulty.

"As soon as the juice has cooled to below 120° F. it is treated with pectin-decomposing material such as Pectinol and as soon as the reaction is complete, indicated by sedimentation of precipitated pectic matter, it is filtered. Any type of filter constructed of impervious metal may be used and the filtering material may be washable cotton pulp, diatomaceous earth or prepared disks of asbestos or paper. Extreme brilliance should not be aimed at as too much filtration tends to reduce flavour; good clarity is all that is necessary.

"The pure or slightly diluted juice is extremely acid and strong flavoured. To make a palatable beverage it should be diluted with water and sweetened, this being done either immediately following filtration or later, according to the following directions:—

"Method A. Flash heat the filtered juice into carboys at a temperature of not under 180° F. and not over 185° F. filling the bottles as full as possible and sealing at once. The juice so treated may then be held in storage and ameliorated, and bottled or canned when required as given under Method B.

"Method B. To the juice add an equal volume of 30° B. sugar syrup. Flash heat into bottles at 180 to 185° F., filling the bottles as full as possible and sealing at once. Stack the filled bottles so that they will cool reasonably quickly. If cans are used, the double enameled type L Charcoal plate type is recommended. The cans are filled full, the covers immediately applied, the filled cans being then inverted and allowed to stand for 3 or 4 minutes before cooling in cold water.

"In Canada, juice to which sugar and water are added may not be labelled as pure, it may, however, be labelled as juice 'with added sugar and water' or as a cocktail with no ingredient declaration.

"Pure juice tests about 2 per cent titratable acid, chiefly citric. To be palatable the finished beverage should test 0.9 per cent to 1.0 per cent acid and this is just about what is obtained by diluting with the sugar syrup.

"Black currants should yield not less than 2 tons of fruit per acre and the average yield obtained at this Laboratory is 160 gallons of juice per ton of fruit. Since one gallon of juice makes 2 gallons of cocktail, an acre should yield not less than 640 gallons, at which rate the growing of black currants for juice purposes should be a profitable undertaking."

Esselen, Powers and Fellers (13) have reported that an attractive apple juice-black currant blend can be prepared by mixing black currant pomace with apple juice and pressing. The resulting juice was found to contain from 25 to 40 mg. of ascorbic acid per 100 ml.

Grape Juice

The commercial production of grape juice in Canada for the years 1942 to 1946 inclusive is as follows:—

TABLE 5—PRODUCTION OF GRAPE JUICE

Year	Quantity	Value
	gal.	\$
1942.....	690,917	362,167
1943.....	234,927	363,476
1944.....	372,101	527,805
1945.....	504,821	690,739
1946.....	783,438	1,064,332

PROCESS

Grape juice is preserved by a number of methods such as pasteurization, cool temperature storage at 28° F. to 30° F., cold or freezing storage, filtering through a germ-proof filter, storage under high pressure carbon dioxide gas, concentration of the juice until the soluble solids are sufficient to effect preservation, and finally some juice is preserved by chemicals.

Only preservation by heat, cool, and frozen storage for deposition of argols will be dealt with here. Also the discussion is intended for the Concord variety or closely related varieties as these are the varieties mainly used for juice in Canada. The grapes are harvested when the total soluble solids content is at least 18 per cent as estimated with a refractometer. Grapes for juice should also be of the best quality in other respects. They should not be green nor should they be too ripe. The grapes are washed and stemmed, crushed, and slowly heated to a temperature of 140 to 145° F. Heating to this temperature releases colour and acid, and facilitates pressing. At least 140° F. is required to release the colour while there is a possibility of obtaining harsh flavours if the temperature exceeds 145° F. The juice is pressed while hot in a hydraulic press, usually employing racks and cloths. Basket presses are also used. The expressed juice is strained and reheated to 170 to 190° F. At this point storage is necessary to allow the argols or crude tartrates to separate. One of the following two processes may be used to accomplish this separation: (a) The heated juice may be filled into warmed carboys, leaving no headspace and using a paraffin coated cork. Cooling is as rapid as practical without breaking the glass. Four months' storage at least is then required for the deposition of argols; (b) The heated juice is cooled with heat exchangers until it is 29 to 31° F. It is then run into large tanks (some approximate 10,000 gallons). The room containing these vats is maintained at 28 to 30° F. With this process one month's storage is sufficient to achieve separation of the argols. In filling large tanks, care should be taken to see that the juice does not become aerated. As a precaution to ensure holding the juice at the recommended temperature, the tanks may be equipped with refrigeration expansion coils. Tanks of almost any size can be equipped in this manner.

When carboy stored juice is to be bottled, the clear juice is siphoned or decanted from above the precipitated argols and sludge. In the case of juice stored at 28 to 30° F., the temperature is raised to 45° F. for 2 days. This higher temperature allows some of the acid to go back into solution. Then the top two-thirds of the tank is siphoned or decanted. This juice is not filtered in order to preserve the best colour and flavour. The addition of sugar will depend upon the nature of the grapes and the demands of the market. The juice is then deaerated and pasteurized. The sludge from the carboys or the bottom third of the large tanks has up to 3 per cent diatomaceous earth added as a filter aid and is filtered. In pasteurizing, the juice is pumped through a flash pasteurizer which will heat the juice to 170-185° F. The bottles or cans* are completely filled so as to eliminate any possible oxidation by air contained in the headspace. The containers are tipped on their sides for 2 to 5 minutes and then cooled. In cooling bottled juice the first sprays should be warm water but the water should get progressively colder until cold water is applied. For canned juice the temperature should be reduced to 100 to 110° F. as quickly as practical. Although the foregoing quick pasteurization at 170° to 185° F. is used successfully under commercial conditions, some manufacturers still follow a process entailing a heating of the juice to 165-180° F., filling into bottles and further pasteurizing 15 to 20 minutes in a water bath heated to the filling temperature. In this case, $\frac{1}{8}$ inch headspace is allowed and

*Special enamel cans have been used to a limited amount in the United States. However, the glass pack continues to be the most important.

cooling is the same as for the quick process. This same precaution with cans would add a 10 to 15 minute process at 212° F. The additional heat treatment does not appear necessary from the standpoint of preservation and affects the colour and flavour deleteriously. After labelling and casing, the juice will keep best in a cool storage.

EQUIPMENT

Similar equipment of stainless steel or other white metal alloys as suggested for tomato and apple juice, is suitable for handling grape juice. Care should be exercised to prevent contamination of the juice by iron or copper equipment.

Apricot, Peach and Prune Purees and Nectars

A line of products being made from these fruits varies from the light juices with some suspended pulp, which are commonly called fruit nectars, to thick purees. The latter are used in ice cream, thickened for dessert toppings, or frozen to make a dessert something like sherbet but with a much higher percentage of fruit (50). These products are grouped here as their manufacture is more or less similar. Fruit for these products should be well ripened, of full flavour and in sound condition.

APRICOT PUREE

Small quantities of apricot puree are being made by canneries from fruit that is too ripe to can as halved apricots. The over-ripe halves are brought to a boil in a kettle with sugar and are then passed through a centrifugal stainless steel pump. This pumping action macerates the pulp sufficiently so that the resulting puree is adaptable for use in ice creams. It is canned in No. 10 cans. This is the simplest process that could be devised. The next forward step would include a steam blancher with a continuous belt and the extraction of the pulp from the fibres with a tomato juice expeller extractor or a disintegrator. The blanching should heat the fruit quickly to at least 190° F. This latter process has been used in the Summerland laboratory and the resulting pulp sweetened to 30 per cent with sugar and canned. This product may be diluted with an equal volume of water if it is to be used as a fruit nectar. Other lots were canned after this dilution and sweetened to 15 per cent total sugar. Such a product has excellent colour and flavour.

PEACH PUREE

Peaches to be handled on a mechanical line require a considerable amount of equipment. In the first place they are peeled through a continuous lye peeler, are then passed through a rough grater and immediately heated in a continuous blancher to 190° F. The heated pulp and stones then pass through a cyclone which separates stones from flesh. The resulting pulp may be handled in a manner similar to apricot puree.

PRUNE PUREE

Prunes are well blanched (190° F.) and passed through a cyclone or finisher. The puree is then treated the same as the apricot and peach puree.

Both canning and freezing are satisfactory preservative methods for these purees and nectars. If preserved by canning, the product is filled into the cans at 190° F. or higher, capped and cooked at 212° F. for 10 minutes. If the

product is to be frozen it is desirable to chill it to 40° F. in a continuous cooler, before packaging. It is then placed immediately in freezing storage at 0° F. or lower.

Sanitation

Possibly no factor in the operation of a juice factory is more important than proper sanitation of the equipment. In the equipment, the hydraulic juice press is the greatest offender. In this equipment the press cloths, racks and trays to catch the juice may all become covered with broken down fruit tissues. This tissue in turn harbours yeast and moulds that can cause fermentation or develop very undesirable flavours in the juice. Consequently the juice press is a starting point for a sanitary program. It is suggested that a small laundry washing machine be installed that will give the press cloths sufficient agitation to remove the cellular apple tissue from between the threads of the weave. After this preliminary cleaning, the cloths can be treated with one of the quaternary ammonium compounds, or other suitable sterilizing agents. In the case of the press racks and the tray for catching the juice, thorough scrubbing is required to remove the apple residue. After this material has been removed the racks can be placed in a tank of water containing the sterilizing compound while the tray can be sprayed with this material. The possibility of better sanitation by use of plastic racks, nylon cloths and stainless steel trays has already been mentioned.

All pipe lines and pumps should be flushed out with fresh water immediately after each operation. By following the juice with water one prevents juice from standing in the sterilizer and possibly burning on to the heated surfaces. All lines, pumps, etc., handling juice can be left full of water containing a sterilizing compound. It is good policy to take down pipe lines frequently to determine if any film is forming on the insides of the pipes. From experience in so doing, an operator can lay out a proper schedule of cleaning so that this film does not have an opportunity of forming. The use of sanitary pipe fittings including cocks cannot be over-emphasized (42).

The 2,500-gallon storage tanks should be scrubbed each time they are emptied, washed thoroughly with clean water and finally sprayed with water containing a sterilizing agent.

The bowl of the filler and the valves dispensing the juice to the cans are offenders if a careful watch is not kept by the superintendent to ensure proper cleaning between shifts. The cans should be cleaned by spraying with cold water, followed by steam and the steam should be followed with a cold water rinse. After these steps the cans should be properly drained before delivery to the filler.

The cooler should also be kept clean. It has been shown in vegetable canning that as the cans cool they may draw organisms from the cooling water through the seam into the canned product thus causing spoilage. When juice is filled at 190° F. a high vacuum is obtained on the can and it is desirable that the cooler should be kept as clean as possible. A slime growth is sometimes found on the walls of cooling equipment. Break-point chlorination of the water is a worthwhile step to prevent the growth of slime moulds. (17, 51). If break-point chlorination is inaugurated for cooling water it can also be used with all the water used in cleaning up the factory and this will ensure a more sanitary plant.

Warehousing

The trend in cannery warehouses is towards high storage rooms and using lift trucks and pallets as a means of conveyance. The most economical height of studding is considered to be 18 to 20 feet. Such a height allows for a

16-foot stack with 1 foot being taken up by pallets. Above the cases there should be approximately 3 feet to allow for ventilation. If a sprinkler system for fire protection is to be installed, then extra space is required for this equipment.

In laying out a storage where a lift truck will be used it is good practice to make the bays large enough to hold a certain number of cases such as 10,000 per unit. Then if all pallets are loaded to the same pattern one can check the inventory very quickly.

Construction of Building

Like all other processing factories, a juice plant should be built so that it can be kept clean. It should be well lighted and well drained. One of the cleanest juice factories observed by the authors used 6-inch square red quarry tile for all walls up to 8 feet and for all floors except in the press room. These tiles were set in an acid and alkali resistant sulphur cement. In the press room, steel decking welded at all joints was used. This gave an impervious floor that is easily cleaned and also provided fairly good traction for the men working about the press. The equipment fits well into bays that are 16 feet wide. A drain should be located in each bay with a slope to the bottom of the drain of 1 inch in 8 feet. The corner formed between the bottom and wall of the drain should be rounded to facilitate cleaning and prevent lodging of refuse. The top of the drain is preferably made of cast iron grating in sections 3 or 4 feet long. The surface should be smooth and flush with the floor. Two pieces of angle iron welded together to form two steps of a stair may be placed in the cement to protect the two corners on each side of the drain. The cast iron grating would rest on the lower step and the top of the grating would be flush with the top of the second. The slope of the floor to the drain should be about 1 inch in 8 feet.

Chemical Aspects and Laboratory Control

FACTORS AFFECTING QUALITY AND NUTRITIVE VALUE OF TOMATO JUICE

Tomato juice is the most important natural source of ascorbic acid (vitamin C) being packed in volume in Canada at a reasonable cost to consumers. When selected varieties of tomatoes are properly grown, prepared, and processed, canned tomato juice should be not only attractive and palatable but also a good source of ascorbic acid. That Canada needs economical food sources of this vitamin was shown in a survey by the Combined Food Board on food consumption levels in the United States, Canada and the United Kingdom (16). They reported that the only vitamin supply seriously deficient in Canada was ascorbic acid. In addition, tomato juice should contribute significant quantities of vitamin A.

A number of factors influence the quality and nutritive value of tomato juice. These will be discussed under several headings. Except for results of work completed during the past two years, much of the information presented here in condensed form may be found in greater detail in two other publications by Strachan and Atkinson (45) and Strachan (44).

THE EFFECT OF VARIETY AND SEASON

While a number of factors may affect the ascorbic acid value of raw tomatoes, the two most important appear to be variety and climate. In Tables 6 and 7 are presented the ascorbic acid values for 42 different varieties and strains of tomatoes grown under the same conditions at the Dominion Experimental Station, Summerland, B.C. (Fig. 25.) Replicate samples of the canned

product were employed for the determination of the ascorbic acid content of the different varieties. This technique has the advantage of convenience and reduction of sampling error. The loss of ascorbic acid in the canning process under proper conditions is insignificant and is comparable for all varieties being tested. For the variety tests reported in Tables 6 and 7, the canned product was stored for 8 months at 50° to 60° F. before being analysed. This treatment resulted in only a very slight reduction of the ascorbic acid content of the canned tomatoes. Due allowance was made for any interference of metallic ions.



FIG. 25. Tomato variety test plots at the Dominion Experimental Station, Summerland, B.C.

It will be noted from Tables 6 and 7 that there was marked variation in the ascorbic acid content of varieties. Also, while there was considerable variation in ascorbic acid values in the same variety from year to year and even from one picking to another, the varieties tended to maintain their relative position to each other especially where average difference was marked. These results are in general agreement with the current literature on this question. The Signet variety developed at the Summerland Station is outstanding in its consistently high ascorbic acid content having a 5-year average of 27 mg. of ascorbic acid. It is of good colour and makes a fine juice tomato but it lacks size for a good commercial canning tomato. Clarks Early and Sugawara have proved to have consistently good ascorbic acid values but are not outstanding. Fortunately, Clarks Early and Sugawara have good cultural and canning characteristics which make them satisfactory canning varieties under commercial conditions in the Okanagan Valley and adjacent areas. Stokesdale No. 4 on two years' trial had a very good ascorbic acid content of 24 to 32 mg. per 100 mg. and has proved to be an excellent tomato for canning. It has a deep attractive red colour which should make it satisfactory for juice also. In recent tests, Sioux and Valiant varieties have been found not only to have a fairly good ascorbic acid content of 19 to 25 mg. but also to have good canning characteristics.

In general, the ascorbic acid contents of the varieties recorded in Tables 6 and 7 compare favourably with the higher results for the same varieties reported in the literature. These high values are probably due in part to favourable climate with respect to temperature and light. Studies by Somers, Hamner and Nelson (41) and Hamner, Bernstein and Maynard (18) illustrate the important role played by

TABLE 6—ASCORBIC ACID CONTENT OF VARIETIES AND STRAINS OF TOMATOES HARVESTED AT SEVERAL DATES OVER A PERIOD OF THREE TO SIX YEARS AT SUMMERLAND, B.C.

Variety or strain	Ascorbic acid content in milligrams per 100 grams*													Average for 3 to 6 years		
	Dates tomatoes harvested and canned															
	1941		1942		1943			1944			1945†				1946	
	Sept. 4	Sept. 22	Sept. 10	Sept. 29	Oct. 19	Sept. 6	Sept. 27	Aug. 24	Sept. 5	Sept. 13	Aug. 29	Sept. 5	Sept. 17			
	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	
Signet.....	33	.....	24	29	35‡	24	34	21	20	.....	21	.....	24	27
Clarks Early.....	.....	32	21	24	23	.....	19	21	20	21	19	.....	23	23
Sugawara.....	25	26	23	26	22	20	19‡	.....	20	.....	.....	23	23	23
Dick Locke.....	.....	22	17	23	23	21	20	19	19	.....	.....	.....	26	22
Sentinel.....	.....	24	16	22	17‡	21	23	.....	21	.....	.....	.....	21	21
Bounty.....	17	21	.....	.....	.....	16‡	21	15	18	.....	21	.....	.....	19

* Calculated to the nearest milligram by increasing 0.5 or over to the next milligram and dropping the decimal point below 0.5.

† After 11 months' storage at 50-60° F.; other years analysed at 8 months' storage.

‡ One sample only.

climatic factors, particularly light intensity or amount of field (polar) illumination, especially for the 18 days prior to harvest, on the ascorbic acid content of tomatoes under field conditions. It is interesting to note from Table 6 that under conditions prevailing, there was no consistent difference in the ascorbic acid content of tomatoes harvested early and late in the season. This is also illustrated under commercial conditions in Table 9.

Truscott (47) has reported on the ascorbic acid content of some 80 tomato varieties grown in Ontario analysed over a 4-year period, 1940-43. Twelve varieties commonly grown for canning in that area, showed ascorbic acid contents in the range of 15 to 38 mg. per 100 g. His data further indicate that while there was considerable variation even within a variety as affected by location and season, most of the tomatoes contained 20 mg. or more of ascorbic acid. This compares favourably with the information presented in Tables 6 and 7 for British Columbia tomatoes.

TABLE 7—ASCORBIC ACID CONTENT OF THIRTY-SIX VARIETIES AND STRAINS OF TOMATOES GROWN AT SUMMERLAND, B.C.*

Variety or strain	Ascorbic acid content in milligrams per 100 grams of canned product**					
	1941 mg.	1942 mg.	1943 mg.	1944 mg.	1945 mg.	1946 mg.
Master Marglobe (Stokes).....	31				21	
Marglobe X Bonny Best.....	30					
Signet X Sugawara.....				30		
Stokesdale (Stokes).....	29					
Hybrid 101.....					29	
Hybrid 107.....					29	
Sugawara X Signet.....			28	28		
Valiant (Stokes).....	28					22
Stokesdale No. 4.....						27
Splendid.....						26
Vetomold.....						26
Hybrid No. 8.....					26	
Hybrid No. 119.....					26	
Globonnie.....	26					
Essary (Univ. of Tenn.).....	26					
Asgrow Scarlet Dawn.....				24		
Hybrid 46 (Mich.).....	24					
Stokesdale No. 48.....						24
California Dawn.....		24	23		18	
Harkness Early.....	25	20	25			
Bestal (Sd.).....	23	25	21			
Earliana Sport (8040).....		25	21		22	19
Rutgers (Vineland).....	22					
Rutgers (Stokes).....	22					
Signet X California Dawn.....				22		
Signet X John Baer.....				22		
Quebec 8.....					22	
Quebec 5.....					21	
Sioux (Neb. and Ore.).....						21
John Baer.....						21
Hybrid 112.....						21
Abel.....	20					
Bulmans Flat (Sd. 993).....			23	15		
Bulmans Special (Flat).....		19	21			
N.D.A.C.....	18					
Bison.....	17					

* With few exceptions the figures given for each year are the average results of two or more pickings.

** Calculated to the nearest milligram by increasing 0.5 or over to the next milligram and dropping the decimal point below 0.5.

The production of a high vitamin C, good quality, heavy yielding tomato with satisfactory canning and juice characteristics appears to be a very urgent problem for the plant breeder. In this connection it is interesting to note that crosses made at the Summerland Station, using a high ascorbic acid variety as one

parent, have given encouraging results indicating the possibilities of developing a variety combining high ascorbic acid content with superior cultural and canning characteristics. Other investigators, Ellis and Hamner (12), Lincoln, Zscheile, Porter, Kohler and Caldwell (25), Maclinn and Fellers (27), and Truscott (47), have shown that not only ascorbic acid but also provitamin A (carotene) content of a variety tends to be an inherent characteristic of that strain or variety (genetic factors) and that tomatoes of increased ascorbic acid or carotene values may be developed by cross breeding. The genetic factor may at times be masked by environmental factors.



Fig. 26. Laboratory Model of Refractometer Covering from 0 to 95 per cent Soluble Solids

ASCORBIC ACID CONTENT OF COMMERCIALY CANNED JUICE AND TOMATOES

A comprehensive study of commercially-canned tomato juice in Canada has revealed marked differences in ascorbic acid content between various brands and between different areas. The results of a survey of the ascorbic acid values of tomato juice and canned tomatoes as commercially produced are presented in Table 8. The most important points to note in this table are: (1) the significantly higher average ascorbic acid content of 18.2 to 22.3 mg. for tomato juice

manufactured in British Columbia compared with 13.0 to 14.2 for Quebec and 15.1 to 15.9 for Ontario; (2) the relatively high minimum values of 12.6 to 15.6 mg. for British Columbia produced tomato juice and the low minimum values of 6.1 to 9.8 mg. for Quebec and 4.3 to 8.6 mg. for Ontario juices; (3) the minimum values for ascorbic acid in canned tomatoes are almost identical for all areas. Consistently, a number of brands were found to be abnormally low. These results suggest that many of the low values for tomato juice are to a large extent due to faulty processing and unsatisfactory equipment, and not to the original raw material. This conclusion is substantiated by the ascorbic acid values presented in Tables 6 and 7 for numerous tomato varieties as grown in British Columbia, and by Truscott (47) for those grown in Ontario.

TABLE 8—ASCORBIC ACID CONTENT OF COMMERCIAL CANNED TOMATO JUICE AND TOMATOES IN CANADA

Year packed	Area	No. of samples analysed	Ascorbic acid values per 100 ml. of juice		
			Average	Maximum	Minimum
			mg.	mg.	mg.
Juice—					
1941.....	British Columbia.....	18	22.3	33.3	12.6
1942.....	Eastern Canada.....	12	14.4	19.5	8.7
1944.....	Quebec.....	44	14.2	26.0	6.1
	Ontario.....	220	15.1	25.0	4.3
	British Columbia.....	54	19.8	26.9	15.6
1947.....	Quebec*.....	80	13.0	15.6	9.8
	Ontario*.....	556	15.9	21.5	8.6
	British Columbia.....	170	18.2	28.8	13.8
			Per 100 grams of tomatoes		
Tomatoes—					
1940-41.....	British Columbia.....	39	21.6	32.4	14.4
1944.....	Quebec.....	5	15.9	18.9	14.1
	Ontario.....	30	17.2	20.3	15.1
	British Columbia.....	53	22.5	27.7	16.3

* Figures of Chemistry Division, Science Service, Ottawa.

COMPARISON OF ASCORBIC ACID CONTENT OF JUICE AND TOMATOES CANNED COMMERCIALY

In order to ascertain how the retention of ascorbic acid in tomato juice compared with that of tomatoes, the data in Table 9 were compiled. The factory from which the samples were secured was well equipped and considered to be packing both products satisfactorily. Under good processing conditions it would appear that on the average the tomato juice contains about 14 per cent less ascorbic acid than do comparable canned tomatoes. A limited survey of juice samples from a number of other factories indicates that losses much greater than this occur. Indications are that tomatoes lose very little ascorbic acid in canning. Unpublished data of the Chemistry Division, Science Service, Ottawa (7) and data presented by Truscott (47) and others, show no significant loss of ascorbic acid in commercial canning of tomatoes.

TABLE 9—ASCORBIC ACID CONTENT OF CANNED TOMATOES AND TOMATO JUICE
PACKED IN SAME DAY AT FACTORY C
(1944 Season)

Sample number	Date packed	Ascorbic acid content per 100 grams	
		Juice	Tomatoes
		mg.	mg.
1.....	Sept. 14.....	16.7	18.5
2.....	" 15.....	21.3	24.3
3.....	" 19.....	20.3	22.9
4.....	" 21.....	15.2	27.7
5.....	" 22.....	21.5	18.9
6.....	" 23.....	17.2	21.1
7.....	" 25.....	22.5	23.2
8.....	" 26.....	22.5	17.8
9.....	" 27.....	18.6	21.7
10.....	" 28.....	20.2	24.3
11.....	" 30.....	19.1	21.1
12.....	" 30.....	19.3	—
13.....	Oct. 2.....	21.4	23.2
14.....	" 3.....	23.5	27.1
15.....	" 5.....	23.2	23.4
16.....	" 6.....	17.2	23.2
17.....	" 7.....	21.2	22.2
18.....	" 11.....	20.1	22.2
19.....	" 13.....	18.4	20.9
20.....	" 16.....	18.1	19.8
21.....	" 16.....	15.7	—
22.....	" 17.....	26.1	31.6
23.....	" 18.....	17.0	24.4
	Average.....	19.8	22.8
	Maximum.....	26.1	27.7
	Minimum.....	15.2	17.8

STUDIES ON RETENTION OF ASCORBIC ACID IN TOMATO JUICE UNDER FACTORY CONDITIONS

In 1943 studies were initiated on ascorbic acid retention under commercial conditions by following the produce as received at the factory through the various processing steps in the plant. This survey was carried out in one plant in 1943 with certain recommendations being made as to improvements in the manufacturing line. The study was repeated in 1944 and 1946 at the same factory as

TABLE 10—RETENTION OF ASCORBIC ACID AT PROGRESSIVE STEPS IN COMMERCIAL
PROCESSING OF TOMATO JUICE

Test No.	Steps in processing	Ascorbic acid per 100 g.
	FACTORY C (1944)	mg.
A 1	Raw tomatoes.....	25.0
2	Emerging from hot break at 200° F.....	22.2
3	In finisher receiving tank at 188-190° F.....	20.7
4	Holding-salting tank (100 gal.) at 183° F.....	19.4
5	After filler prior to sealing can at 183° F.....	19.3
6	After canned juice stored three weeks.....	19.2
B 1	Raw tomatoes.....	20.8
2	Emerging from hot break at 200° F.....	19.6
3	In finisher receiving tank at 188-190° F.....	19.2
4	Holding-salting tank (100 gal.) at 183° F.....	17.2
5	After canned juice stored three weeks.....	17.3

well as two additional factories. The results of the study at Factory C in 1944 are given in Table 10. This factory has what is considered to be a very good tomato juice manufacturing line. A hot break of 190°F. to 200°F. is used. Salting tanks are also employed but normally the juice remains in these tanks less than 10 minutes. Losses were, in general, smaller and less variable at this plant than in the other two plants investigated. The ascorbic acid figures recorded in Table 10 for raw fruit are very approximate due to the fact that only 12 to 16 fruits were analysed whereas the other figures represent a volume of 50 to 100 gallons of juice or equivalent to around 700 to 1,400 pounds of tomatoes. It is unlikely that there was a significant loss at this plant in the hot break due to the few seconds only required to reach the inactivating temperature of 190°F. following milling. Hence, this figure probably should be taken as representing more nearly the true average ascorbic acid value of the raw product being employed during the tests. On this basis the total loss in processing under good conditions was 2 to 3 mg. or 11.7 to 13.5 per cent. The per cent loss or retention may be misleading as it varies with the quantity of ascorbic acid present, whereas the loss should be relatively constant at 2 to 3 mg. or less irrespective of the per cent ascorbic acid originally present in the fruit. These results are in good agreement with those reported by Robinson, Stotz and Kertesz (38) who stated that under efficient manufacturing conditions, tomato juice should contain at least 80 per cent of the ascorbic acid content of the trimmed tomatoes. Loss at Factory A was only very slightly greater than at C, but Factory B showed a loss of 18.1 to 26.9 per cent. This was probably due to low temperature extraction with excessive holding time, allowing enzyme action together with aeration of the product. Losses greater than those found could be expected under such conditions and these losses would be greater than at the other factories. None of the factories studied permitted contact of the product with copper equipment.

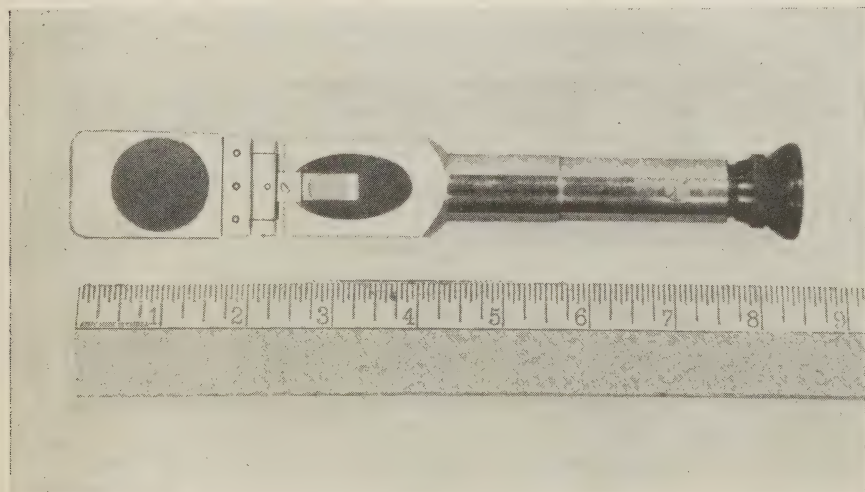


FIG. 27. Hand Refractometer especially suitable for field work. These instruments are usually supplied with ranges to cover 0—40 per cent and 30—85 per cent

Studies in 1946 at a factory employing a continuous juice line of the type recommended by the Summerland laboratory and "hot break" extraction was found to have an apparent retention of over 90 per cent, loss being less than 2 mg. per 100 g.

EFFECT OF THE METHOD OF EXTRACTION ON THE ASCORBIC ACID CONTENT

All tests were made on the same lot of raw tomatoes. Pulping and preheating were carried out in a stainless steel jacketed kettle. Only stainless steel or inert metal equipment was employed. Cans were, in each test, filled full at 190° F., sealed, processed 10 minutes at 212° F. and water cooled. The results obtained by the different extractions may be accentuated over those obtained under commercial conditions due to somewhat greater time factors under experimental conditions.

The important point brought out in Table 11 is the necessity of rapid heating of the milled pulp to sufficiently high temperature (at least 190° F.) and to pass in

TABLE 11—EFFECT OF THE METHOD OF EXTRACTION ON THE ASCORBIC ACID CONTENT OF EXPERIMENTALLY PREPARED CANNED TOMATO JUICE

Test No.	Method of extraction	Ascorbic acid per 100 ml.	Percent loss compared to Lot K
		mg.	%
A	Pulped and boiled 3 to 4 min. Extracted hot through screen.....	30.2	8.5
B	Pulped and boiled $\frac{1}{2}$ to 1 min. Extracted hot through screen.....	29.6	10.3
C	Pulped and heated to 173° F. Extracted hot through screen.....	22.4	32.1
D	Pulped and heated to 110° F. Extracted immediately.....	22.9	30.6
E	Scalded whole 3 min. in boiling water, pulped and extracted immediately through screen.....	24.5	25.8
F	Scalded whole 2 min. in flowing steam, pulped and extracted immediately through screen.....	22.9	30.6
G	Pulped and cold extracted through screen.....	22.5	31.8
H	Pulped and cold extracted through centrifugal juicer.....	21.8	33.9
I	Pulped and cold extracted through screw expeller press.....	21.0	36.4
J	Pulped and boiled $\frac{1}{2}$ to 1 min. Extracted hot through small centrifugal juicer.....	25.2	23.6
K	Pulped and boiled $\frac{1}{2}$ to 1 min. Extracted hot through small screw expeller press.....	33.0	0.0

a few seconds through the temperature range of most rapid vitamin C destruction. If this is done, loss of ascorbic acid is relatively small but if not, the loss may be serious as indicated in Table 11 where as much as 36 per cent loss occurred. The actual method of extraction appeared to be of little consequence provided the extraction was on pulp heated to 190° F. to 210° F. This temperature has the additional advantage that it also inactivates pectin-destroying enzymes resulting in improved consistency of juice as pointed out by Kertesz and Loconti (23). Recently Clifcorn and Peterson (10) have reported that there is a rapid loss of ascorbic acid in tomato juice saturated with air, increasing directly with temperature up to 186° F., then with further increase in temperature a sudden drop in the rate of vitamin C destruction occurred. This is in general agreement with the authors' results. However, they found this loss to be due to some unknown factor other than enzyme, the rate of destruction being directly related to oxygen or air content and temperature of the juice.

Since the oxidizing enzymes are located almost entirely in the skin, Wokes and Organ (49) and the Chemistry Division, Science Service, Ottawa (8) with very little present in the juice or other tissue of the tomato, it would appear that steam blanching to inactivate the enzyme in the skin might be effective in reducing loss of ascorbic acid during extraction. However, it was found in experiments at the Summerland laboratory where whole tomatoes were scalded in steam for 2 minutes or in boiling water for 3 minutes, that the losses in ascorbic acid were still 30.6 and 25.8 per cent respectively, Table 11. Then by deducting 8.5 per cent for screen extraction, net losses of 22.1 and 17.3 per cent were encountered compared to complete inactivation and screw expeller extraction. Also, it would appear from recent studies at the Summerland laboratory that

tomatoes can be extracted cold in a commercial screw expeller juice machine with about the same loss as tomatoes extracted hot, *provided the juice is immediately heated in a matter of seconds to at least 190° F.*

EFFECT OF STERILIZING TEMPERATURE AND PERIOD

In Table 12 are presented the results of experiments to determine the effect of sterilizing temperatures and period on ascorbic acid content of canned tomato juice. Each lot number represents a separate experiment, thus (a) and (b) can be compared but not one lot with another in respect to ascorbic acid content. Cans were filled full at 190° F. and after the heat treatment indicated were water cooled. The results show that the sterilizing temperature and length of cook had very little effect on the final ascorbic acid content of canned tomato juice. This is in agreement with limited data obtained in 1943 under commercial conditions. It was observed, however, that excessive processing temperatures with long processing time had a deleterious effect upon colour and flavour.

TABLE 12—EFFECT OF STERILIZING TEMPERATURE AND PERIOD ON ASCORBIC ACID CONTENT OF EXPERIMENTALLY CANNED TOMATO JUICE

Lot No.	Processing data		Ascorbic acid per 100 ml.
	Sterilizing process	Period	
		min.	mg.
1 (a)	210° F. (Boiling water).....	10	26.2
(b)	(Held on side in air).....	5	26.5
2 (a)	240° F. (Retort).....	10	26.6
(b)	210° F. (Boiling water).....	10	26.3
3 (a)	240° F. (Retort).....	20	27.9
(b)	210° F. (Boiling water).....	10	29.3
4 (a)	250° F. (Retort).....	5	24.9
(b)	210° F. (Boiling water).....	10	25.9
5 (a)	250° F. (Retort).....	15	26.8
(b)	210° F. (Boiling water).....	10	28.0

EFFECT OF TIME AND TEMPERATURE OF STORAGE

Samples of tomato juice, some of which were fortified with ascorbic acid at the rate of 50 mg. per 100 ml., were packed in glass and tin and then stored at three different temperatures, 32° F., 55-60° F., and 65-80° F. Analyses were made at intervals of 7, 10, 16, 19 and 24 months. Insignificant loss occurred in all cases at 32° F. This loss never exceeded 5 per cent even after 24 months' storage. Loss was greatest at the highest temperature range (65-80° F.) being 6 to 8 mg. for unfortified and 14 to 18 mg. per 100 ml. for fortified juice after 24 months' storage. This is a retention of at least 74 per cent. Approximately the same percentage of ascorbic acid was lost from both the unfortified and fortified juice. At the 55-60° F. range the loss of ascorbic acid was only about one-half that at the higher temperatures of 65-80° F.

Reduction of ascorbic acid during the first 7 months at all storage temperatures was negligible, being less than 1 mg. The rate of loss tended to increase thereafter, especially between the 10 and 16 months' period.

While differences were small, the tin packed product tended to retain the ascorbic acid slightly better than the glass packed, allowance having been made for interference of reducing ions. No noticeable difference in colour or flavour was detected between the unfortified or fortified juice.

In summary of this study it may be concluded that tomato juice should retain after customary prevailing storage temperatures of 55-80° F., the following percentage ascorbic acid, 98, 92, 81 and 74 per cent after 7, 10, 16 and 24 months respectively.

These results agree in general with those of other investigators where storage conditions are comparable up to periods of 13 months. Fellers and Buck (14) reported the retention of ascorbic acid in glass packed tomato juice stored at 70° F. to be about 86 per cent after 6 months and 80 per cent after 12 months. These authors also found most of the loss occurred in the first two or three months in storage which is not in agreement with the writers' results. On commercial samples stored at 40° F. and 78° F., Sale et al (39) found storage losses at 12 months to be approximately 10 and 21 per cent respectively. Cohee and Goodale (11) confirmed the writers' results that plain and fortified (90 mg. ascorbic acid per 100 ml. added) tomato juice lost approximately the same percentage of its ascorbic acid content during storage. These authors reported the per cent retention to be 95.0 to 99.7 per cent, 80.3 to 89.4 per cent, and 49.7 to 51.9 per cent after 3, 8 and 20 months at warehouse storage (40 to 95° F.) respectively. Their losses at 20 month storage are much greater than those found by the writers.

Moschette, Hinman and Halliday (30) found no significant loss of ascorbic acid in canned tomato juice stored at 50° F. for 12 months. Retention at 65° F. was also good, being approximately 95 per cent. With 80° F. storage, losses were greater, retention being 80 to 90 per cent which is in agreement with results of the Summerland laboratory.

COMPOSITION OF TOMATO JUICE CANNED IN CANADA

Table 13 gives the proximate composition of 346 samples of commercially canned tomato juice from the 1944 pack. These samples are segregated according to the production area. It will be noted that there is no significant difference in most constituents between the various sections of the country where tomato juice is packed commercially. The only marked difference due to area appears to be in the ascorbic acid content as shown in Table 13. Analyses at this Laboratory and studies by Saywell and Cruess (40) and others indicate that the sugar in tomatoes or tomato juice is practically all reducing, the sucrose content normally being less than .05 per cent.

Limited studies on vitamin A content (carotene value) of British Columbia tomato juice after 9 months' storage at 60° F. indicate an extreme range of about 450 to 950 micrograms per 100 grams with an average figure of 740. Most values seem to fall between 600 and 800 micrograms with no apparent significant difference being found between commercial varieties grown in British Columbia. Seasonal and area variations have yet to be investigated. Vitamin A content of tomatoes appears to be well retained on processing. Also in general the loss of carotene during storage, even at relatively high temperatures of 80° F. is very small. The retention is about 95 per cent after 12 months according to Fellers and Buck (14) and Moschette, Hinman and Halliday (30).

GRADING OF COMMERCIAL JUICE ON BASIS OF ASCORBIC ACID RETENTION

In order to obtain a basis on which to establish standards several hundred commercial samples were analysed for ascorbic acid. Fifteen milligrams has been discussed as a minimum content for Fancy quality, while 10 and 7.5 mg. have both been suggested for Choice quality. Table 14 shows the results of these analyses and indicates that a standard of not less than 10 mg. could be reasonably met for Choice quality.

TABLE 13—COMPOSITION OF COMMERCIAL TOMATO JUICE CANNED IN CANADA DURING 1944

Area	Constituents per cent by weight								
	Soluble* solids	Refractive* index	Specific** gravity	Total solids	Insoluble solids	Sugar as invert	Total acid	pH	Salt
	%			%	%	%	%		%
<i>Br. Columbia</i>									
Average.....	6.3	1.3423	1.028	6.55	0.78	3.33	0.462	4.28	0.59
Maximum.....	8.6	1.3459	1.039	8.92	1.04	4.09	0.773	4.41	1.35
Minimum.....	5.2	1.3408	1.023	5.49	0.56	2.31	0.244	4.12	0.08
No. samples....	66	66	66	62	47	60	64	64	64
<i>Ontario</i>									
Average.....	6.3	1.3423	1.028	6.49	0.61	3.19	0.443	4.20	0.72
Maximum.....	8.2	1.3452	1.037	8.48	0.98	4.49	0.583	4.42	1.43
Minimum.....	4.8	1.3401	1.021	4.88	0.53	1.99	0.326	4.02	0.09
No. samples....	232	232	232	232	167	218	232	232	232
<i>Quebec</i>									
Average.....	6.3	1.3424	1.028	6.58	0.73	3.32	0.446	4.21	0.67
Maximum.....	7.9	1.3447	1.035	8.05	0.95	4.04	0.578	4.38	1.50
Minimum.....	5.0	1.3409	1.022	5.33	0.54	2.61	0.345	4.06	0.14
No. samples....	48	48	48	48	32	44	48	48	48

* By refractometer at 20° C.

** Calculated from index of refraction at 20° C. according to Table 3, National Canners Association Bul. No. 27-L, Revised 1941. (4).

TABLE 14—PERCENTAGE OF SAMPLES OF COMMERCIALY CANNED TOMATO JUICE IN RANGES THAT MAY BE USED AS GRADING STANDARDS

Province	Number of samples	Percentage over 15 mg.	Percentage less than 15 mg.	Percentage less than 10 mg.	Percentage less than 7.5 mg.
		%	%	%	%
British Columbia..... 1944	54	100	0.0	0.0	0.0
..... 1947	170	94.1	5.9	0.0	0.0
Ontario..... 1944	220	44.1	55.9	5.4	0.9
..... 1947	556	74.6	25.4	1.6	0.0
Quebec..... 1944	43	58.1	41.9	16.3	9.3
..... 1947	80	6.3	93.7	5.0	0.0

RELATIONSHIP OF ANALYSIS TO QUALITY IN APPLE JUICE

It is difficult to say what chemical analysis constitutes a good flavoured apple juice because of so many inconsistencies. However, it would appear to be fairly definite that a soluble solid content as determined by refractometer of over 12.5 per cent is necessary for a juice of good flavour and body. A soluble solid to acid ratio is more practical than a sugar to acid ratio. Many consumers favour a ratio of 22 to 26 per cent soluble solids to 1 per cent of acid. When this ratio becomes less than 20 to 1, the product tastes progressively more acid or sharp. Thus, a juice of 12.5 to 13.0 per cent soluble solids usually has the most desirable flavour with a total acid content of 0.50 to 0.55 per cent. When the soluble solids exceed 13 per cent, an acid content of 0.55 to 0.65 is usually preferred. Juice of soluble solids less than 12 per cent tend to be lower in flavour and may be flat or sharp depending on the acid content. Juices with

much less than 0.50 per cent acid tend to lack character and be flat or insipid, while those with an acidity greater than 0.65 per cent tend to be sharp unless there is a marked increase in soluble solids as well.

Mottern et al (31) examined numerous commercial samples of apple juice packed in the United States in 1940 and found that most of the better samples had an acidity of about 0.5 per cent. In a similar survey of the juice packed in 1946, Heller (20) and associates reported that juices having a Brix reading above 13 degrees were usually better flavoured than those having less. A Brix (Balling) reading of 13 on apple juice would approximate a specific gravity of 1.052 or refractometer soluble solids reading of 12.6. The refractometer gives the most accurate determination of soluble solids.

Arengo-Jones (2) states that fresh juice to be processed should test approximately as follows: "specific gravity 1.055, acid 0.5 to 0.6 per cent by volume as malic, tannin 0.06 to 0.1 per cent by volume as tannic acid. Astringency is of less importance than the correct sugar-acid ratio, though it should not be above 0.1 per cent." This is in general agreement except that the tannic acid values appear relatively high which may be due possibly to the method of analysis. A specific gravity of 1.055 corresponds closely with 13.5 per cent soluble solids and the sugar-acid ratios would be then approximately 23 to 27 of sugar to 1 of acid.

Studies at this Station and by other investigators elsewhere, Caldwell (6) and Clague and Fellers (9) show that considerable variation exists in chemical composition of the juice from the same variety from season to season.

TABLE 15—ANALYSES OF COMMERCIAL APPLE JUICES PRODUCED IN BRITISH COLUMBIA FROM 1944-47

—	Soluble solids (Refractometer)	Specific gravity @ 15.5 C. by hydrometer	Total acid (malic)	pH	Ascorbic acid mg./100 ml.
	%		%		mg.
Average.....	12.6	1.049	0.54	3.54	41.5
Maximum.....	14.9	1.062	0.88	3.90	48.8
Minimum.....	9.7	1.040*	0.26†	3.26	22.3‡
No. samples.....	422	387	407		150

* Nine samples or 2.3% of those analysed had a specific gravity less than 1.045.

† Twenty samples (4.9% of those analysed) had an acidity of less than 0.4%.

‡ Only 8 samples or 5.3% of those analysed contained less than 35 mg. of ascorbic acid per 100 ml. of juice. Values less than 35 mg. indicate faulty plant laboratory control.

TABLE 16—ANALYSES OF COMMERCIAL SAMPLES OF APPLELIME JUICE PRODUCED IN BRITISH COLUMBIA DURING 1947

	Soluble* solids	Specific** gravity	Total acid (malic)	pH
	%		%	
Average.....	12.3	1.050	0.73	3.33
Maximum.....	13.0	1.053	0.93	3.59
Minimum.....	11.4	1.046	0.47	3.12
No. samples.....	37	39	39	39

* By refractometer at 20°C.

** By hydrometer at 15.5°C.

TABLE 17—PROXIMATE ANALYSES OF SEVERAL COMMERCIAL BRANDS OF BRITISH COLUMBIA CLARIFIED AND CRUSHED TYPE APPLE JUICE ANALYSED AFTER SEVERAL MONTHS' STORAGE (68° F.)

Brand	Date packed	Soluble solids (refractometer)	Specific gravity @ 15.5 C. by hydrometer	Total solids (dry wt.)	Sugar as invert			Total acid (malic)	pH	Pectin as calcium pectate	Ash	Alkalinity ¹ of ash	Tannin	Centrifuged solids
					Total	Reducing	Sucrose							
		%		%	%	%	%	%		%	%		%	%
1	Nov. 1942...	12.8	1.052	12.76	10.41	9.21	1.20	0.41	3.63	0.15	0.27	32.0		
1	"	13.0	1.054	12.99	11.18	9.10	2.08	0.49	3.61	0.04	0.19	31.0		
1	Nov. 1944...	12.8	1.051		10.92			0.62	3.52				0.066	
2	Oct. 1942...	10.6	1.043	10.48	9.36	8.07	1.29	0.36	3.55	0.17	0.20	27.0		
2	Dec. 1942...	11.9		11.82	10.40	9.07	1.33	0.41	3.60		0.16			
2	"	11.0	1.050	12.14	10.50	9.17	1.33	0.43				25.0		
2	Jan. 1943...	11.9	1.050	11.96	10.52	9.10	1.42	0.40	3.61	0.15	0.17	30.0		
3	Nov. 1942...	11.9	1.049	11.65	10.24	8.87	1.37	0.49	3.56		0.19	29.0		
3	"	12.6	1.052	12.60	11.10	10.00	1.10	0.56	3.46					
3	"	11.9	1.050	11.94	10.48	9.10	1.38	0.52	3.55		0.23			
3	Nov. 1944...	12.0	1.047		10.44	8.48	1.96	0.52	3.50				0.033	
3	Jan. 1943...	12.0	1.050	12.19	10.50	9.40	1.10	0.51	3.40	0.08	0.28	40.0		
4	Oct. 1944...	13.2	1.055		11.56	7.76	3.80	0.60	3.45					
4	"	13.4	1.057		11.76	7.98	3.78	0.66	3.41					
4	"	12.6	1.052		11.03	8.27	2.76	0.59	3.49					
4	Nov. 1944...	12.3	1.053		11.64	9.24	2.40	0.57	3.43					
4	"	13.8	1.058		11.92			0.60	3.40					
4	"	12.0	1.049		10.04			0.57	3.52				0.079	12.0
4	"	12.5	1.051		10.93			0.53	3.40				0.056	10.0
4	"	13.0	1.053		11.04	7.92	3.12	0.54	3.44				0.077	8.0
4	"	12.2	1.050		11.04	8.11	2.70	0.54	3.45				0.060	25.0
4	"		1.048		10.81	7.87	2.73	0.51	3.43				0.057	11.0
4	"	12.0			10.60			0.51					0.076	16.0

¹ ml. of 0.1 N hydrochloric acid per 100 gram sample.² percent of pulp by volume after centrifuging 15 ml. juice for 5 min. @ 2200 r.p.m.

NOTE.—Brands 1, 2, and 3 are clarified (clear) apple juice. Brand 4 is crushed type containing cellular solids.

FORTIFICATION OF JUICES OTHER THAN APPLE

Investigations at the Summerland Laboratory have shown that if desired both tomato juice and grape juice may be satisfactorily fortified with synthetic ascorbic acid at the rate of 50 mg. per 100 ml. After ten months, storage at room temperature the fortified bottled grape juice retained 90 per cent of the added ascorbic acid. Cohee and Goodale (11) have reported on the addition of ascorbic acid to tomato juice. Esselen, Powers and Fellers (13) state that added 1-ascorbic acid is quite stable in processed apple, cranberry and grape juices when these products are fortified at the rate of 50 mg. per 100 ml. They also found that ascorbic acid had a favourable effect on colour retention in cranberry and apple juice, but had no significant effect on colour or flavour of grape juice.

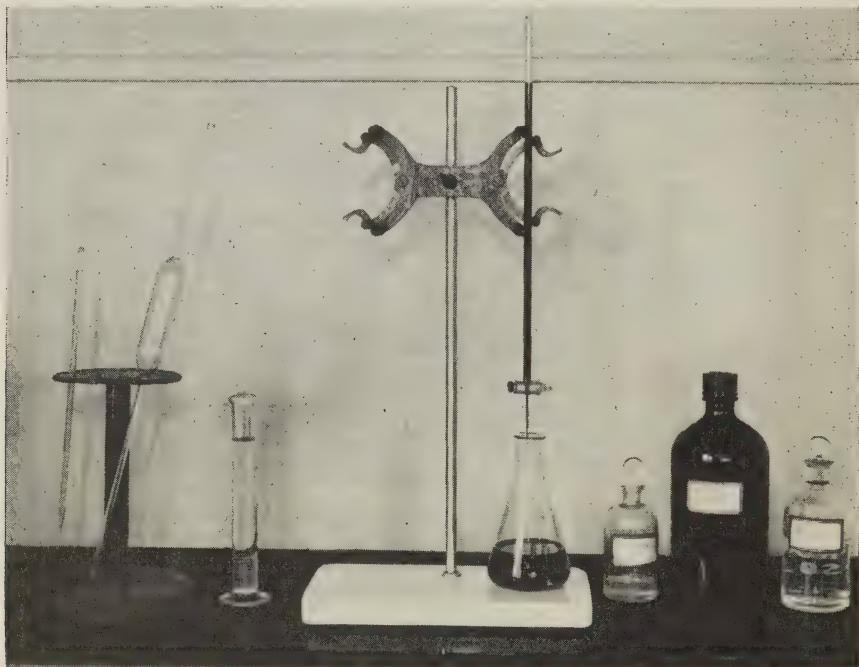


FIG. 28. Apparatus for determining ascorbic acid in fortified apple juice. Left to right: 5 ml. measuring pipette, 100 ml. volumetric pipette, 100 ml. graduated cylinder, burette support and clamp, 10 ml. burette, 500 ml. erlenmeyer flask, starch indicator, standardized iodine, and sulphuric acid solution.

CONTROL LABORATORY AND METHODS OF ANALYSIS

The control laboratory is an essential unit in a juice manufacturing establishment as the products should be standardized from day to day as much as possible. Also, the Meat and Canned Foods Act specifies such standards as the mould count tolerance on tomato juice, and the specific gravity, and acid in apple juices that it is necessary for the manufacturer to meet. Without the control laboratory, the manufacturer may incur considerable loss through packing a product such as tomato juice with a mould count above the tolerance.

The laboratory should be equipped to make tests such as soluble solids with a refractometer, or hydrometers with scales such as Baume, Brix, Balling or Specific Gravity; to analyse for sucrose and invert sugars; total acid; pH; tannin; ascorbic acid (vitamin C); and Howard Mould Count. Detailed and

accurate methods for these determinations are given in the A.O.A.C. Methods of Analysis (32) in the chapters on "Fruits and Fruit Products", "Vitamins" and "Extraneous Materials in Foods and Drugs (tomato products)." Often, however, the detailed and laborious, though accurate method, is not required for factory control. Consequently there are the so-called "quick methods" that are sometimes sufficiently accurate for the task in the factory. Before they are adopted, however, the chemist should check results obtained against those obtained by official methods. Comments on the tests suggested are given in the following paragraphs.

Soluble solids by refractometer

Readings on a refractometer equipped with a sugar scale, reading in per cent by weight, indicate the soluble solids present in the juice, Figures 26 and 27. As the soluble solids are 60 to 90 per cent sugar depending upon the product, the refractometer reading serves as a guide to the sugar content. The reading serves as a very useful figure in blending products or in determining sugar-acid ratios. The reading is more quickly and easily made than with a hydrometer and is more accurate because of the elimination of the element of viscosity. Also, temperature does not affect it to the same extent. Consequently, for most purposes this instrument replaces the older specific gravity, Balling or Baume hydrometer methods.

With apple juice, the soluble solids as determined with a refractometer may be converted to approximate specific gravity. This is accomplished by multiplying the soluble solids figure by the factor 4 and substituting the result for the second and third decimal places of the specific gravity of water, 1.000. For example, with an apple juice of 12.0 per cent refractometer reading, the calculation would be as follows: $4 \times 12 = 48$ and this figure substituted for the second and third decimals gives 1.048 specific gravity. The extreme range in specific gravity which will be found in most apple juices is 1.040 to 1.065.

Soluble solids and specific gravity by hydrometer

Balling, Brix, Baume and specific gravity reading hydrometers have been used frequently in the past as a convenient means of expressing relative sweetness since these readings in a juice are to some extent proportional to the sugar content of the juice. Specific gravity hydrometer reading is essential under present grading regulations for apple juice.

Sugars (total, reducing and sucrose)

The Lane-Eynon volumetric method as described in the A.O.A.C. Methods of Analysis is very satisfactory, and requires no expensive equipment. At this laboratory it has been found most satisfactory to invert sucrose by gently boiling the clarified diluted solution for 10 minutes in the presence of 5 per cent citric acid (100 ml. of solution plus 5 grams of crystalline citric acid), cooling, neutralizing and continuing the analysis as given in the Official Methods.

Total acid:

This is a valuable determination in estimating sugar-acid ratios and palatability. It is also required for grading apple juice. It may be determined satisfactorily by simple titration employing an indicator (phenolphthalein) or a glass electrode pH meter to estimate the end point. The latter instrument is preferable, especially in highly coloured products. (5) (32).

pH value:

This figure indicates the active acidity and is a further guide to palatability. The pH value is of the highest importance in establishing processing schedules. It may be quickly and accurately determined with a glass electrode pH meter.

Tannin:

This determination is a measure of astringency. It is estimated as in a recent issue of the Journal of the A.O.A.C. (19.)

Ascorbic acid (vitamin C)

The determination of ascorbic acid in fortified juice is essential. Also the ascorbic acid content is a good index of processing technique and quality in tomato juice. It may become a factor in grading tomato juice. The official method for determination of ascorbic acid is the sodium 2,6 dichlorophenolindophenol dye titration procedure employing a visual end point (32). Experience in the Summerland laboratory has shown that 0.4 per cent oxalic acid solution as suggested by Ponting (36) may be satisfactorily substituted for the metaphosphoric-acetic acid stabilizing extracting solution employed in the official method. If traces of iron are present and interfering with the titration, a truer result can be obtained by using 8 per cent acetic acid as the dilution medium in place of oxalic or metaphosphoric acid. Five to ten second end point is taken normally. In the case of highly coloured products, it is necessary to use a photometric method (21,26) since it is impossible to see the end point accurately. Ascorbic acid in tomato and apple juice may be estimated accurately by visual titration.

A simple, rapid, inexpensive and accurate chemical method which has been found to be very suitable for factory control purposes has been developed by Strachan and Moyls (46) of the Summerland laboratory. This method as described is only suitable for fortified apple juice.

Mould count in tomato juice (Howard)

The maximum tolerance is set for presence of mould in tomato juice for human consumption. There is a definite relationship between the amount of mould present in the juice and the soundness of the raw material, the carefulness of preparation, and the sanitary conditions throughout the plant. The method of mould counting is fully described in the A.O.A.C. Methods of Analysis (32) and also in the National Canners Association Bulletin. (4)

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American Can Co. Ltd., Vancouver, B.C. . .	Fig. 8
B.C. Equipment Ltd., Vancouver, B.C. . . .	Fig. 17
B.C. Fruit Processors Ltd., Kelowna, B.C..	Fig. 20
Berlin Chapman Co., Berlin, Wisconsin . .	Figs. 2 and 4
Britton, J. E., Dom. Exp. Station, Summerland, B.C.	Figs. 15, 16, 23, 24, 26, 27, 28
Chisholm-Ryder Co., Niagara Falls, Ont. . .	Figs. 3, 5, 6, 7
Food Machinery Corp., San Jose, Calif. . .	Figs. 9, 10, 11, 12, 13, 22
Niagara Filter Corp., Niagara Falls, Ont..	Figs. 18 and 19

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